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TRANSACTION

1. A Study on the Digestive System and Feeding Habits of Fish

By Yasuo SUYEHIRO

Imperial Fisheries Experimental Station

(With 190 Text-figures, 18 Tables and I-XV Plates

(Received April 15, 1941)

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Introduction

From olden times, researches regarding the digestive system and the feeding habits of fish have been made time and again in various countries, and reports, as shown later, on these studies have been submitted in countless numbers. But up to the present time not one report has been written giving a combined and general study of the digestive system and the feeding habits of so many species at one time.

Since 1929, I have been engaged in the study using mostly the time after office hours under the kind guidance of Prof. Ikusaku Amemiya of the Tokyo Imperial University. In the course of the study, Dr. Nobuichi Kasuga, the Director of the Station, Prof. Seiho Nishi and Dr. Ryûta Usui gave me valuable suggestions, kind advices, encouragement as well as facility for the study in every way. I here express my hearty thanks to those benefactors. I am also much indebted to many other gentlemen in connection with the completion of the study. The names of them are recorded at the end of this treatise.

The publication of the present study is enabled by the financial aid of the Keimei-Kwai. I express my sincere gratitude to its commitee.

Material and Method

MATERIAL

Being especially favoured by geographical and oceanographical conditions, Japan abounds in fish species and for the present study those having almost all kinds of habits and habitats were collected and used. Thus, the study is based upon the examination of as many as 150 species, belonging to 88 families and 132 genera of teleost. The names of them are shown below.

No.	Family	Species	Japanese name
1	Dorosomatidae	*Clupanodon punctatus*	Konosiro
2	Dussumieriidae	*Etrumeus micropus*	Urumeiwasi
3		*Spratelloides japonicus*	Kibinago
4	Clupeidae	*Clupea pallasii*	Nisin
5		*Sardinia melanosticta*	Maiwasi
6		*Harengula zunasi*	Sappa
7	Engraulidae	*Engraulis japonicus*	Katakutiiwasi
8		*Coilia mystus*	Etu
9	Salmonidae	*Oncorhynchus keta*	Sake
10		*O. nerka*	Benimasu
11		*O. masou*	Masu
12		*Salvelinus leucomaenis pluvius*	Iwana
13	Plecoglossidae	*Plecoglossus altivelis*	Ayu
14	Osmeridae	*Hypomesus olidus*	Wakasagi
15	Salangidae	*Salangichthys microdon*	Sirauwo
16	Synodontidae	*Saurida undosquamis*	Maesa
17	Myctophidae	*Dasiscopelus spinosus*	Ibarahadaka
18	Cyprinodontidae	*Aplocheilus latipes*	Medaka
19	Siluridae	*Parasilurus asotus*	Namazu
20		*Plotosus anguillaris*	Gonzui
21	Cyprinidae	*Gnathopogon caerulescens*	Honmoroko
22		*Sarcocheilichthys variegatus*	Higai
23		*Tribolodon hakonensis*	Ugui
24		*Carassius auratus*	Huna
25		*Cyprinus carpio*	Koi
26	Cobitidae	*Misgurnus anguillicaudatus*	Dozyô
27		*Cobitis biwae*	Simadozyô
28	Anguillidae	*Anguilla japonica*	Unagi
29	Congridae	*Astroconger myriaster*	Maanago
30		*Alleconger anagoides*	Hanaanago
31	Muraenesocidae	*Muraenesox cinereus*	Hamo
32	Nemichthyidae	*Nemichthys scolopaceus*	Turuunagi
33	Muraenidae	*Gymnothorax kidako*	Utubo
34	Fistulariidae	*Fistularia petimba*	Akayagara
35	Syngnathidae	*Syngnathus schlegeli*	Yôziuwo

36		*Hippocampus coronatus*	Tatuno'otosigo
37	Belonidae	*Athlennes anastomella*	Datu
38	Hemirhamphidae	*Hemirhamphus sajori*	Sayori
39	Exocoetidae	*Cypsilurus agoo*	Tobiuwo
40		*C. japonicus*	Hamatobiuwo
41	Scombresocidae	*Cololabis saira*	Sanma
42	Trachypteridae	*Trachypterus iris*	Tengaihata
43	Sphyraenidae	*Sphyraena pinguis*	Akakamasu
44	Mugilidae	*Mugil cephalus*	Bora
45	Atherinidae	*Atherina bleekeri*	Tôgorôiwasi
46		*A. tsurugae*	Gin'isoiwasi
47	Zeidae	*Zeus japonicus*	Matôdai
48	Berycidae	*Beryx splendens*	Kinmedai
49	Monocentridae	*Monocentris japonicus*	Matukasauwo
50	Scombridae	*Scomber japonicus*	Saba
51	Katsuwonidae	*Katsuwonus vagans*	Katuwo
52	Thunnidae	*Thunnus orientalis*	Maguro
53		*Parathunnus sibi*	Mebati
54		*Neothunnus macropterus*	Kihada
55	Cybiidae	*Sawara niphonia*	Sawara
56	Trichiuridae	*Trichiurus haumela*	Tatiuwo
57	Istiophoridae	*Makaira mitsukurii*	Makaziki
58	Xiphiidae	*Xiphias gladius*	Mekaziki
59	Coryphaenidae	*Coryphaena hippurus*	Siira
60	Bramidae	*Brama raii*	Simagatuwo
61	Stromateidae	*Psenopsis anomala*	Ibodai
62	Pampidae	*Stromateoides argenteus*	Managatuwo
63	Carangidae	*Trachurus japonicus*	Maazi
64		*Decapterus muroadsi*	Muroazi
65		*Alectis ciliaris*	Itohikiazi
66		*Seriola quinqueradiata*	Buri
67		*S. aureovittata*	Hiramasa
68		*S. purpurascens*	Kanpati
69	Leiognathidae	*Leiognathus nuchalis*	Hiiragi
70	Trichodontidae	*Arctoscopus japonicus*	Hatahata
71	Oplegnathidae	*Oplegnathus fasciatus*	Isidai
72		*O. punctatus*	Isigakidai
73	Mullidae	*Upeneus bensasi*	Himezi
74	Cepolidae	*Acanthocepola krusensterni*	Akatati
75	Branchiostegidae	*Branchiostegus japonicus*	Akaamadai
76	Apogonidae	*Apogon lineatus*	Tenzikudai
77		*A. semilineatus*	Nenbutudai
78	Scombropidae	*Scombrops boops*	Mutu
79	Serranidae	*Lateolabrax japonicus*	Susuki
80		*Bryttosus kawamebari*	Oyanirami

81		*Stereolepis ischinagi*	Isinagi
82		*Epinephelus septemfasciatus*	Mahata
83	Sciaenidae	*Nibea mitsukurii*	Nibe
84		*N. argentata*	Isimoti
85	Sillaginidae	*Sillago sihama*	Kisu
86		*S. japonica*	Awogisu
87	Girellidae	*Girella punctata*	Mezina
88	Sparidae	*Pagrosomus major*	Madai
89		*Taius tumifrons*	Kidai
90		*Sparus swinhonis*	Kurodai
91	Pomadasyidae	*Hapalogenys mucronatus*	Setonai
92	Theraponidae	*Therapon oxyrhynchus*	Simaisaki
93	Aplodactylidae	*Goniistius zonatus*	Takanohadai
94	Embiotocidae	*Ditrema temmincki*	Umitanago
95	Labridae	*Halichoeres poecilopterus*	Kyûsen
96		*Pseudolabrus japonicus*	Sasanohabera
97	Callyodontidae	*Leptoscarus japonicus*	Budai
98	Chaetodontidae	*Chaetodon modestus*	Genrokudai
99	Siganidae	*Siganus fuscescens*	Aigo
100	Triacanthidae	*Triacanthus brevirostris*	Gima
101	Balistidae	*Canthidermis rotundatus*	Amimongara
102	Monacanthidae	*Monacanthus cirrhifer*	Kawahagi
103	Ostraciidae	*Aracana aculeata*	Itomakihugu
104	Tetraodontidae	*Sphaeroides rubripes*	Torahugu
105		*S. vermicularis*	Syôsaihugu
106	Molidae	*Mola mola*.	Manbô
107	Scorpaenidae	*Sebastodes inermis*	Mebaru
108		*S. flammeus*	Sankômenuke
109		*S. matsubarae*	Akô
110		*S. iracundus*	Ôsaga
111		*S. baramenuke*	Baramenuke
112		*Sebastiscus marmoratus*	Kasago
113		*Inimicus japonicus*	Oniokoze
114	Hexagrammidae	*Hexagrammos otakii*	Ainame
115		*Agrammus agrammus*	Kuzime
116	Cottidae	*Pseudoblennius percoides*	Anahaze
117		*P. cottoides*	Asahianahaze
118		*P. marmoratus*	Ayaanahaze
119	Platycephalidae	*Platycephalus indicus*	Koti
120		*Inegocia japonica*	Tokagegoti
121	Agonidae	*Podothecus acipenserinus*	—
122	Triglidae	*Lepidotrigla microptera*	Kanagasira
123	Gobiidae	*Pterogobius elapoides*	Kinubari
124		*Chasmicthys dolichognathus galosus*	Dorome
125		*C. d. dolichognathus*	Agohaze

126		*Periophthalmus cantonensis*	Mutugorô
127		*Boleophthalmus pectinirostris*	Tobihaze
128		*Trypauchen vagina microcephalus*	Akauwo
129	Echeneidae	*Echeneis brachyptera*	Kurokoban
130	Uranoscopidae	*Uranoscopus japonicus*	Misimaokoze
131	Ammodytidae	*Ammodytes personatus*	Ikanago
132	Blenniidae	*Salarias enosimae*	Kaeruwo
133		*Enedrias nebulosus*	Ginpo
134		*Dinogunellus grigorjewi*	Nagazuka
135	Ophidiidae	*Otophidium asiro*	Asiro
136	Pleuronectidae	*Paralichthys olivaceus*	Hirame
137		*Atheresthes evermanni*	Aburagarei
138		*Hippoglossoides elassodon*	Umagarei
139		*Lepidopsetta mochigarei*	Asabagarei
140		*Limanda yokohamae*	Makogarei
141		*Kareius bicoloratus*	Isigarei
142	Cynoglossidae	*Rhinoplagusia japonica*	Kurousinosita
143		*Areliscus joyneri*	Akasitabirame
144	Gadidae	*Gadus macrocephalus*	Tara
145		*Theragra chalcogramma*	Suketôdara
146		*Eleginus navaga*	Komai
147		*Lotella phycis*	Isoainame
148	Lophiidae	*Lophius litulon*	Kiankô
149	Antennariidae	*Pterophryne histrio*	Hanaokoze
150		*Antennarius tridens*	Izariuwo

METHOD

I. Method of Examining the Digestive System.

As it is essential to know the normal form of the digestive system, I examined 3 to 10 of each species which could be easily collected, but for the rare species, there were times when I could examine only 1 sample.

I took my material while they were alive, or fresh, and put them in ca. 10% formalin or ca. 70% alcohol, or fixed them with other chemicals for observation. Then, I examined them macroscopically in the order of the mouth, jaws, lips, teeth on vomer and palatines, tongue, pharyngeal teeth, gill-rakers, pharynx, oesophagus, stomach, intestine, rectum, pyloric appendages, liver, gall-bladder, pancreas, etc. and paid special attention to the form and construction of the digestive tracts.

1) Jaw teeth.

The villi-form teeth, which are the common kind, may be examined either as they are or fixed with chemicals, but for special kinds of teeth, such as the anchylosed strong teeth, it is better to observe them after boiling the jaws and removing the muscle and skin, and taking out the maxillary, premaxillary and the mandible. It is advisable to clean them with a hard toothbrush.

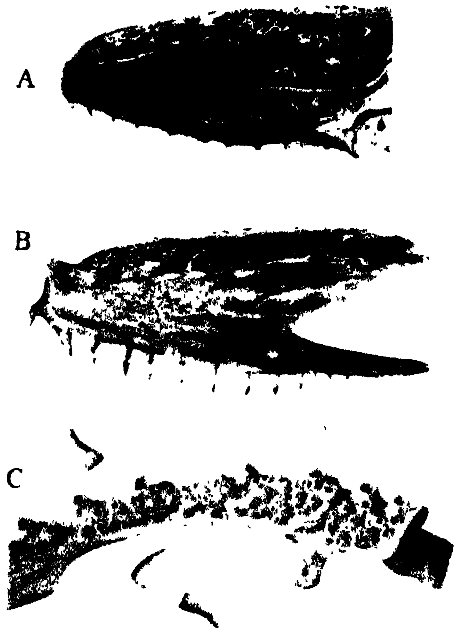

Fig. 1. Method of observing anchylosed and hinged jaw-teeth A Upper jaw of *Scombrops boops*. B. Premaxillary was taken out by boiling the above. Note how well the anchylosed jaw-teeth may be observed. C. Hinged jaw-teeth of *Gadus macrocephalus*

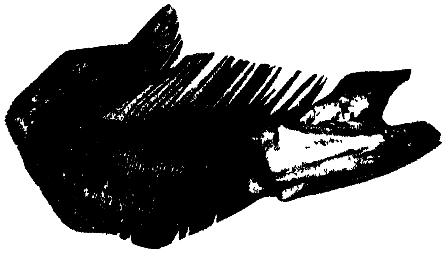

Fig. 2. Method of observing gill-rakers.

For hinged teeth, first, while they are fresh, it is better to observe carefully the direction in which they move, then boil and observe their attachment.

2) Teeth on vomer, palatines and pharyngeal bones.

Excluding the special kinds, I examined them fixed with chemical solutions, brushing them thoroughly as in the case of the jaw teeth.

3) Gill-rakers.

While they were fresh I took out the gill-rakers together with the gill-arches, as illustrated, and washed them. There was hardly any discernible difference in their appearance as when they were fresh and after they had been fixed with a chemical solution. When the processes on the gill-rakers were exceptionally minute, it was necessary to make a microscopical observation.

4) Digestive organs.

As the digestive tract and the liver are subject to easy self-decomposition. one must either make as quick an examination as possible after collecting the fishes, or fix them with a solution. It would be advisable to fix those with thick peritoneal muscles after dissecting a part of the peritoneal wall, or by injecting the solution with a pipette from the anus.

In making a morphological study of the digestive organs, as it is absolutely essential to keep intact their natural positions (an item which I most emphatically insist on advocating in my present study), one must refrain from taking out the internal organs before they are fixed. In doing this, formalin is better than alcohol, and fixing for about 3 days in the former is advisable. When it is left too long in the solution, the blood changes colour, and it not only makes observation of the blood vessel difficult but also the liver oil becomes extracted, thus, exposing the entire observation to inadequacy and incompleteness.

After the fishes have been properly fixed, dissect the peritoneal walls and expose the internal organs. Then, inserting a knife at the beginning of the oesphagus and the end of the rectum (if the anus can be included, all the better), cut and take out very carefully for observation. (The liver breaks very easily).

In observing the digestive organs of small fishes, such as those that belong to the family Cyprinodontidae, the usual method hitherto employed was to make a number of cross sections and use the reconstruction method, but I followed the following method: first, as shown in the illustration, I cut off the head with a sharp knife, then by placing the triangular piece which I had cut off by running the knife along the upper part of the peritoneal cavity within the field of a binocular dissecting miscroscope, by taking out the internal organs with 2 needles, I succeeded in making a microscopical observation. As one becomes experienced in this method, it is not only easily done but a more accurate observation may be obtained.

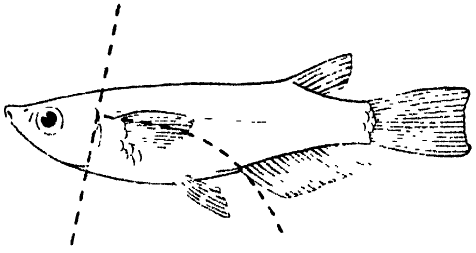

Fig. 3. Method of observing digestive tract of small fish such as *Aplocheilus latipes.*

I made sketches in the larger digestive organs by using a proportional compass and in the smaller ones with a camera lucida.

There are certain species of fish which it is difficult to distinguish the stomach. For instance, in the case of the order Plectognathi. However, if one observes the folds of mucous membranes of the digestive tracts of these fishes, one will be able to distinguish the stomach from the intestine. But if it is still not possible to distinguish them by this method, put them under histological observation and ascertain microscopically whether or not there are any gastric glands.

After laying the intestine, as best I could, in its natural form without stretching it, I observed its type of winding; then, as illustrated, measured its length. It is essential to select fishes which have little or no contents in their stomach, or fishes in aquarium which were made to fast, because the folds of mucous membrane of the stomach and intestine in which

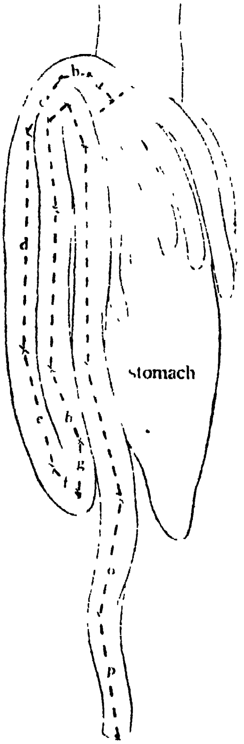

Fig. 4. Method of measuring length of intestine. a+b+c+d+ · +p= total length of intestine.

there is food, as may be seen from the illustration, lose their natural form. I took every precaution to follow this procedure. The digestive tract thus extracted was dissected and washed. After brushing away the food remnant between the papillae, the folds of the mucous membrane were ready for observation. For narrow intestines like those of sardines, it is better to fix them with a chemical solution first; then dissect a piece of the intestine and cut open properly; spread this piece on top of a cork; lay a thin piece of cotton and a square piece of paraffin paper on it, and pin down the 4 corners. Then put this cork upside down in a vessel filled with fresh water for one night. The intestine will be well prepared for observation and photographtaking the next day.

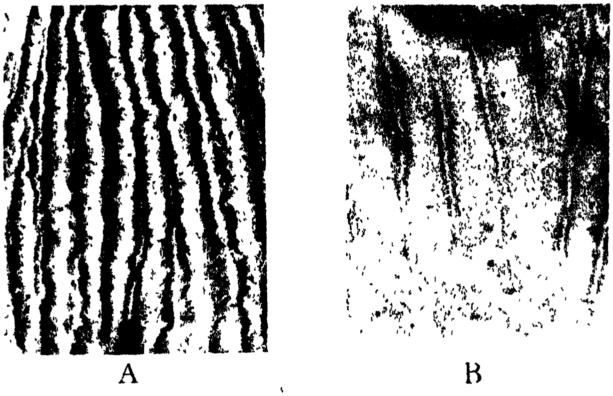

Fig. 5. Method of observing folds of mucous membrane of stomach. A. Good specimen. B. Poor specimen.

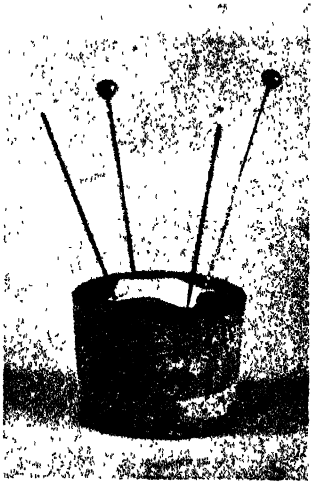

Fig. 6. Method of lay-opening narrow intestine.

II. Method of Examining the Feeding Habits.

Definite opinions may be formed only after making a thorough investigation of the feeding habits of numerous fishes collected in different places at various times. It is therefore well nigh impossible for anyone to complete the investigation of the feeding habits of 150 species during one's lifetime. But fortunately for me, there were countless number of reports on this subject, especially important fishes, written by former investigators with which to compare and compound my own studies in an endeavour to form an accurate and definite opinion of my own.

In most cases, the contents taken from the stomachs were broken in pieces; however, there were not few instances in which they kept their original form so well that it was possible to identify their species, but in the majority of cases, I had to trouble the specialists concerned in making their identifications.

Historical Review

Before going into the main part of the present study, I wish to give an outline of the history of works made by various scholars of different nations regarding the digestive system of fishes and their food and feeding habits. I have devoted the past 10 years to the collection of literatures. However, I am sure that the reader will readily realise that the number of literatures any one individual is able to read during any given time is limited, and due to the difficulty of obtaining the foreign literatures in our country, especially those of small countries and ancient times, I shall have to content myself with what is within my power to reach. As a matter of fact, when I have not been able to read the originals, I have been forced to be satisfied with the reproduced articles or abstracts of those originals which have been written in the reports of others.

DIGESTIVE SYSTEM

General Treatise

A study on the structure of the digestive system of fishes had already been made no less than 2250 years ago by Aristotle (384–322 B. C.). In his notable book entitled " Historia animalium ", there are seen the results of his research about the various organs of mankind as well as of various fishes. As for the digestive system of fishes, to my astonishment, a brief but surprisingly accurate observation about the teeth, the tongue, the stomach, the intestine, the liver and even the gall-bladder was made by him.

About 500 years after this, Galenus (130–200) who is called the father of anatomy, dissected and studied the lower vertebrates, and about 1000 years thereafter Leonardo da Vinci (1452–1519) not only made anatomy of human beings but various other animals. However, it is not certain whether these men went so far as to study the digestive system of fishes.

According to Cuvier and others, the first man who undertook the systematic study of comparative anatomy was Severinus, an Italian anatomist. It is said that in his " Zootomia democritae " (1615) he used a magnifying lens and observed the internal organs of herring, sardine and dog-fish. Leewenhoek (1687), who is known as the inventor of microscope, also contributed materially to the anatomy of fishes in connection with his study of various animals, but it is uncertain whether he made the anatomical study of the digestive system or not.

I am of the opinion that the first contribution that was ever made toward the study of only the digestive system of fishes is " A general idea of the structure of the internal parts of fish " by Preston (1697), and fortunately I have had the opportunity of reading through this paper. In this he dealt with the structure of the stomach of fish, the winding of its intestine, the liver, the gall-bladder, the bile duct, the pancreas (he erroneously referred to the pyloric appendages as the pancreas).

For about 80 years afterwards a few reports were written on the digestive system of fishes, but Cuvier (1773–1838) who paved the way for modern comparative anatomy, in truth was the first person studied in general the digestive system of fishes from a purely anatomical standpoint. In his well known books: "Leçons d'anatomie comparée" (consisting of 8 volumes—1799–1805. Volume IV is devoted to the study of the teeth, the livers and pancreases of fishes, and Vol. V to their digestive tracts); "Vorlesungen über vergleichende anatomie" (in I volumes; 1809–1810. Vol. III contains a certain amount of information on fishes; this was translated by Meckel); "Le règne animal" (in 4 volumes; 1817. An anatomical study of fishes is given in Vol. III); and "Histoire naturelle des poissons" (co-author, Valenciennes. 22 volumes; 1828–1849. Vol. I takes *Perca* for the material and describes the structure of its internal organs), he gave an anatomical study of all the organs of digestive system of fishes, comparing them with those in various other vertebrates. These writings are not only important for their historical significance but also from their scientific standpoint.

Next we have Rudolphi of Germany and Home of England, both of whom published the distinguished works on comparative anatomy. The former, in Vol. II and III (1802), and the latter, in Vol. I and II (1814), wrote on the general structure of the digestive system of fishes. From 1821 to 1833, Meckel of Germany, wrote a book consisting of 6 volumes on the same subject, in the IV and VI volumes of which, he gave an acount of the digestive organs and the gills of fishes.

Not long afterward, Carus of Germany published his popular works in 2 volumes in 1834, (which was translated into French by Jourdan in 1835), Stannius, his characteristic writing, and Owen, an Englishman, a book on the comparative anatomy of vertebrates. The last published 3 volumes from 1866 to 1868, in Vol. 1, Chapter 5, of which he gave an original study of the teeth, the digestive tract, the liver, the pyloric appendages of fishes. Then Huxley (1871) published a book on the anatomy of vertebrates, observing their digestive system in a singular way. Next we have Book I (anatomy of vertebrates, including fishes) of Nuhn (1875), a German anatomist. His study is characteristic in respect of describing not only the structure of organs but also their functions. A German anatomist, Vogt and his assistant, Yung wrote a text-book of comparative anatomy in German and French; in this they explained the structure of each organ of the digestive system, taking *Perca fluviatilis* for the material of study. This book consists in 2 volumes, and was published from 1880 to 1894. Also, about the same time, Wiedersheim wrote 2 separate books on the comparative anatomy of vertebrates. One of them, published in 1884, was purely a treatise on comparative anatomy, while the other, published in 1886, took up and treated the subject from an embryological standpoint. As Wiedersheim was well versed on the subject of fishes, his work on the comparative anatomy of the digestive system of fishes was excellent and fully original.

The foregoing studies and researches were principally macroscopic. However, Oppel, a German anatomist, who specially concentrated his efforts to the histological study of the digestive system of vertebrates, treated all the organs of vertebrates microscopically, and gathered his works and others in a famous book entitled "Lehrbuch der vergleichenden mikroskopischen Anatomie der Wirbeltiere" (Pt. I published in 1896; Pt. II in 1897; Pt. III in 1900), and thus he completed the so-called comparative microscopic anatomy. Details in connection with the histology of the digestive system of fishes was stated in each chapter.

In the latter part of the 19th century and the beginning of the 20th, there was a tendency for medical scientists, especially German anatomists, in studying the comparative anatomy, to take fishes for their materials, as the result of which, the study of the digestive system of fishes made a great progress. About this time, Gegenbaur wrote a book entitled "Vergleichende Anatomie der Wirbelthiere", which even in the present time is considered one of the most important books of reference in this line of study (published in 1898 Vol. I, and in 1901 Vol. II). This is an ingeniously combined piece of work of the studies hitherto made and those of the author himself, and he gives an extensive and comprehensive account of the digestive system of fishes chiefly in Vol. II.

Some original work since the days of Gegenbaur, with regard to the digestive system in general of fishes can be seen in the text-book of Haller, a German anatomist. As Haller was well informed in this line of study and in a position to discuss the vivisection of fishes, in a book published in 1904, he viewed, in an independent way, the relationship between the form and function of the teeth, the tongue, the stomach, the intestine, the pyloric appendages, and the mucous membrane of the digestive tract. Following this, Schinkewitsch, a Russian (1910), and Bütschli, a German (1912), published some books dealing with the comparative anatomy, but there are no original ideas and suggestions worthy of note concerning the digestive system of fishes.

And thus we came to our contemporaries. "Handbuch der vergleichenden Anatomie der Wirbeltiere" in 6 Volumes, published by Urban and Schwarzenberg in Berlin (1931–1938), wrote by the world's greatest scholars of comparative anatomy, was consequently authoritative and progressive insofar as the study of comparative anatomy was concerned. As may be contended from a book of this kind, the studies relating to each part of the digestive system of fishes are complete in every detail.

Böker, in his recent edition "Vergleichende biologische Anatomie", in Vol. II (1937), in the chapter "Biologische Anatomie der Ernährung", he expressed his original views on the connection the digestive system of fishes has with its feeding habits. In addition to the books mentioned above specializing on fishes, Günther (1880), Jordan (1907), Haempel (1912), Bridge (1922), and Kyle (1926), discussed in general the digestive system of fishes in an individual way, but there is very little originality in their statements.

Fish in Japan from time immemorial has been studied from 2 standpoints, namely, for catering purposes and for something to gaze and admire.

In this connection, there are a few books giving quite a bit of detailed information as to the names and form thereof. But, up to the year 1890, no books had been written concerning to the anatomy of fishes, and, as for books on comparative anatomy, the one which was recently published by Nishi (1929) is the fiirst and unique in Japan. However, the book of Kawamoto "Gyorui no seiri" published quite recently (1935), in view of the fact that it took for its subject matter the anatomical physiology of fishes, furnished some excellent notes on their digestive system which, along with the personal researches of the author, contributed not little to this branch of study.

Now the first person in Japan who studied the digestive system of fishes, nay, the internal parts, was Namie (1895). He made anatomy of *Plecoglossus altivelis* caught in the Tama river and made clear the form and the situation of its teeth, the tongue, the stomach, the intestine, the pyloric appendages, and the liver. Then, the original works of the anatomy of general digestive system of fishes were made in succession by Gotô with *Cynias manazo*, *Raja kenojei* and *Carassius auratus* (1900), by Kishinouye with *Clupea melanosticta* (1907), by T. Fujita with *Pagrosomus major* and *Cyprinus carpio* (1912), and by Hikita with the flat-fishes (Pleuronectidae) (1934).

And I have made a thorough study of the digestive system of *Gadus macrocephalus* (1934), *Theragra chalcogramma* (1934), *Lepidopsetta mochigarei* (1934), *Hippoglossoides elassodon* (1934), *Monacanthus cirrhifer* (1934), *Triborodon hakonensis* (1934), *Cypsilurus agoo* (1935), *Oplegnathus fasciatus* (1935), *Plecoglossus altivelis* (1935), *Chasmichthys gulosus* (1935), and *Goniistius zonatus* (1936), keeping the structure of their digestive tracts foremost in mind and studying, at the same time, their feeding habits, on the results of which I have already reported. However, I have not yet written any report on the experiments I have made on the digestive systems of about 150 kinds of fishes. And it is now my endeavour to synthesize those works and present them to the reader in this treatise.

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I have above given the history of the comparative anatomy regarding the general digestive system of fishes compared with those of other animals and now I will give the historical outline of the studies made upon each special organ of the digestive system in fishes.

Mouth and mouth part

The form of the fish mouth being used for the description in the classification, and so, from old times many systematicians have paid their attentions to it, but not many anatomists have taken up the form of mouth of fishes for the main object of their studies.

To begin with, Nuhn (1875) dealt in his book which I have already stated with the comparative anatomy regarding the mouths of *Labrus*, *Gadus*, *Box*, and *Syngnathus*, while Humphry (1865) and Bardeleben (1907), when studied the jaws of various vertebrates, made study on the jaws of fishes. Jourdain (1878), Garman (1913) and Radcliffe (1916) specialized in this study too, but their studies were confined to sharks and rays, and did not deal with teleosts.

As regards the common jaws of teleosts, aside from the fact that systematicians have dealt with them when they were classifying fishes, no one has ever made a special study of their form. On the contrary, perhaps it is because that the projecting jaws attract more attention, there are reports, written as far back as in the 17th century, on the upper projecting jaws of the sword fish and its kind (and also its function such as to pierce whales and fishing-boats). Since Josselyn (1674) published his work, reports have been written on the similar article by Koelpin (1770, 1771), Thompson (1844), Gray (1871), Wilcox (1887), Maclaren (1909), Boulenger (1931), H. Nakamura (1938). And Uchida (1930) wrote a article on the lower projecting jaw of *Hyporhamphus sajori*.

The cylindrical or tube-like jaws of *Syngnathus* and *Hippocampus* were first studied by Gill (1905) and later by Rauther (1925). Uchida studied the life history of *Hyporhamphus sajori*, and ascertained that its long lower jaw was not only useless when taking its food but was rather a hindrance. When Gill made an extensive study on the life history of *Hippocampus*, he observed the structure of its jaw, and noticed that it used its jaw like a pipette and caught the minute creatures in the water. In addition, Rauther found that both *Syngnathus* and *Hippocampus* resemble each other not only in the structure of their jaws but in their characteristic feeding habits. With regard to the various phases of the cylindrical jaws, Böker (1937) described those in the chapter, viz. " Das Ergreifen der Nahrung " of his book.

The majority of fishes possess the " protrusile mouth ", and it has much connection to the feeding habits. Regarding this, Freund (1909) studied with *Cyprinus carpio*, Hesse and Doflein (1910) with *Abramis brama*, Petersen (1914) with *Gadus morrhua*, but the first person who made a comparative study of this was Thilo (1920). He accomplished some very splendid and original work regarding the construction of jaws, and their function which constituted a protrusile mouth. This research was done chiefly with such fishes as *Clupea*, *Salmo*, *Coregonus*, *Cobitis*, *Gasterosteus*, *Zeus*, *Triacanthus*, *Tetrodon*, and various others. Then we have Delsman (1925) and Dobben (1935) who published their studies which were practically along the same lines as those above. Other than the more popular articles on the connection between the form of the jaws and the feeding habits of fishes, literature is not available, but I would like to mention that Beebe and Tee-van (1933) gave an account of the intimate relation between the form of the mouth and the feeding habits of the fishes caught in the waters of Bermuda. Their writing may have a tendency to popularity, still they may well be regarded as original works.

As there are many fishes that possess barbels, one would think that this had attracted the attention of scientists from olden times, but it is surprising to note the scarceness of literature dealing with this subject. Moreover, it was only towards the end of the 19th century that Jobert (1871, 1872, 1873) published his works concerning this. And it is thought that he was one of the first to make a systematic study of the barbels of fishes. He was also interested in the palps of insects and contributed materially to the study at large of the barbels of fishes from an anatomical stand-point. About the same time Zincone (1876) made a study of the tactile organs of the Italian *Mullus*, *Motella*, *Blennius*, and *Trigla*. As the barbel of the catfish is most familiar among the barbels of fishes, it has naturally been more popular as an object of study, and such persons as Wright (1884), Herrick (1901, 1903), and Olmsted (1918), etc. were the ones to engage themselves in this study. Further, Atôda, (1935) made some very interesting study as regards the development of the maxillary and mental barbels of the larval fish of the Japanese catfish, viz. *Parasilurus asotus*. As for the form and function of barbels, insofar as the food is concerned, when Bateson (1890) studied the form of the eyes, olfactory and sense organs and their functions of various fishes, he made a thorough study of them; while Steven (1930) taking the 3 varieties of the Triglidae for his material, made experimental studies of the function of barbel. Recently, some very significant work has been accomplished by Satô (1936, 1937) regarding the morphology and histology of barbels of various Japanese fishes, such as *Paramyscine atami*, *Pristiophorus japonicus*, *Cyprinus carpio*, *Polymixia japonica*, *Byotula multibarbata*, *Misgurnus anguillicaudatus*, *Physiculus japonicus*, *Coelorhynchus japonicus*, *Apistus evolans*, *Upenoides bensasi* and *Plotosus anguillaris*. He was successful in classifying the barbels into 2 groups, one that has a cutaneous taste-bud on the surface of the epidermis layer and one without it.

The study on the muscles in the mouth part of fishes is important for determining the mode of their feeding habits. As for this, Cuvier wrote the results of his study in his book "Histoire naturelle des poissons" (1828). In Vol. I, page 404 of this book, there is an article on the muscles of the mouth of *Perca*. The next important writing after the publication of Cuvier's book is the study made by Vetter (1878). He made a study of the adductor mandibulae of the fishes, viz. *Esox cucis*, *Perca fluviatilis*, *Cyprinus carpio*, *Barbus vulgaris*. This is the first comparative study ever made of the muscles of the mouth, and in after-years, his work was cited by many scholars. In 1911, Edgeworth studied on the cranial muscles of various vertebrates; and in his study, he took it upon himself to study the muscles of the mouths of *Amia*, *Salmo*, *Trutta*, *Lepidosteus*, *Acipenser*, etc.. Then Holmquist (1911) took *Gadus callarias*, Greene (1913) took the king salmon, and Dietz (1914) took Acanthopterygii for their materials and made the similar studies. In Japan, Takahashi (1925) studied the cranial muscles of 3 different groups of fishes, namely, the Cyprinoids, the Cobitoids and the Siluroids, and discussed the homology of their cranial muscles.

Jaw Teeth

In view of the fact that the jaw teeth play an important part in the classification of fishes, it has been studied by both systematicians and anatomists, but the minute studies have been made, in general, by anotomists, so

I wish to introduce here mainly the contributions of the latter.

The first complete report on this subject from a historical point of view can be found in Cuvier's "Leçons d'anatomie comparée", Vol. IV, Book I (1835). However, it is unanimously agreed by specialists that the first and fundamental work on the teeth of fishes was done by Owen (1840–1845). In Vol. I, Chapter 5, "Teeth of Clenoid fishes", of his book, he gave a detailed description of the rounded molars of *Pagrus;* the conical teeth of *Sciaena;* the carding teeth of *Gobius;* the setiform teeth of *Chaetodon;* the minute teeth of *Mugil* and *Clupea;* the small teeth of *Atherina;* the strong teeth of *Pelamys;* the movable teeth of *Lophius;* and the sharp teeth of *Trichiurus* (not only the jaw teeth but also the pharyngeal teeth), etc. Then there is Heincke (1873) who studied the development of the teeth of lower vertebrates, as also those of fishes; Boas (1878) who discovered the succession of the teeth of Scaroid fishes; Baume (1882) and Röse (1892, 1896) who concentrated their efforts to the comparative dental anatomy of vertebrates, including fishes, and Ridewood (1896) who devoted himself solely to the study of the teeth of fishes. In the 20th century, Terra (1911) who made a comparative and systematic study of the teeth of human beings and those of vertebrates, studied those of fishes. The comparative studies which deal exclusively with the histology of teeth of fishes were made by Röse (1897) and others, and the excellent work which concerns specially the development of the teeth of teleosts was done by Friedmann (1897).

Thus, Tomes compiled the 5 reports he had written from 1875 to 1900 and published his famous "A manual of dental anatomy, human and comparative". He not only classified in a very logical and orderly way the forms of teeth of various fishes and other animals but wrote in detail on their attachment, histological construction (enamel structure), development, succession, and functions. A little later, Thompson and Dewey (1915) studied the construction of the teeth of vertebrates and invertebrates in general (chiefly regarding their attachment and succession), using X-ray. They took many photographs of the teeth and made a complete and detailed report. Recently, Böker (1937) studied the teeth of various fishes from a standpoint of biological anatomy, and observed that the form of the teeth and their feeding habits had a very close connection to one another, and Peyer (1937), combining his previous works and the works of others, wrote a paper entitled "Zähne und Gebiss" regarding the teeth of vertebrates in general, which is considered the most authoritative literature ever written insofar as the modern comparative dental anatomy is concerned, and in which he gave a great deal of original studies on the teeth of fishes. In addition to the above-mentioned contributions, a fairly complete description of the conclusive studies of the teeth of fishes is seen in the books of comparative anatomy, especially in those of Stannius (1848), Owen (1866), Wiedersheim (1884), Gegenbaur (1901), Haller (1904) or in the text-book of fishes by Günther (1880).

Although the comparative studies made on the teeth of fishes are as I have stated previously, a great deal of effort has been paid in the study of the jaw teeth of a certain group or one species of fishes, especially, for example, the sharp teeth or the peculiar teeth; this I believe is due to the fact that such teeth insure our attention. As for such teeth of the wolf-fish, Andre (1784) studied them with *Anarrhichas lupus* (as also *Chaetodon nigricans*), and said that its anterior sharp teeth was principally used in seizing its prey while the posterior grinding teeth served to break down or crack open the hard shells of lobsters, crabs, etc. Crisp (1853) also stated of this fish that its teeth was used to break or crush the hard food. Gill (1911) who studied the habits of various fishes belonging to the family Anarrhichadidae, dealt with the teeth of those fishes from the standpoints of the ichthylogical classification and the feeding habits.

The study of the characteristic teeth of Salmonidae was undertaken by Knox (1855); the teeth of *Echeneis* by Murrery (1899); and those of *Orthagoriscus* were studied by Hilgendorf (1893); while Schmidt (1913) studied the arrangement, the size, the number, the form and the function thereof of *Cyclopterus lumpus*, as also their histology and development. The recent report of Tretjakoff (1926) on the histological and embryological study of the teeth of Plectognathi is a prominent contribution towards this branch of study.

There is hardly any literature dealing with this line of study in our country, especially in ancient times. But if we look hard enough, we can find reference to the serrated teeth of Japanese cutlass-fish in "Yamato honzô" of Kaibara (1715). Besides which there is an article written by Namie (1891) as to the characteristic construction of the teeth of *Plecoglossus altivelis* and the connection between the development of teeth and the feeding habits. Kishinouye (1901) gave us an original and fairly detailed report regarding the form and arrangement of the canine-like and molar teeth in the jaws of *Pagrus major*, *Pagrus tumifrons*, and *Pagrus cardinalis*. And M. Fujita (1924) made a brief report on the form and arrangement of the jaw teeth of various Japanese fishes. As regards the form and number of the jaw teeth of Japanese flat-fishes caught in northern Japanese waters, Hikita (1934) gave us a complete and detailed report. The above-mentioned studies in our country, however, are limited only to the external observation of the teeth, and do not touch on the special studies of the teeth of fishes. The only exclusive study that was ever made of the teeth of fishes is the recent report submitted by Hiyama (1931), and I believe that this was the first of its kind to accomplish anything in our country. He studied particularly the form, the arrangement, the histology, the development, the growth and the functions of the soldered jaw teeth of *Oplegnathus fasciatus*.

Tongue

As the fish is the lowest kind of animal that possesses a tongue, in making a study of it, the first two points that become an object of discussion among the scholars is whether or not it has a muscle to control it like the other vertebrates, or whether it has the power to distinguish various tastes. In view of this point at issue, the studies heretofore made have primarily dealt with these two questions.

Cuvier wrote in Vol. IV of his "Leçons d'anatomie comparée" that *Anguilla*, *Conger* and the other fishes which belong to Apodes have a muscle on both sides of the tongue called the M. hyoglossus, which starts from the hyoid. But Ludwig (1854) later pointed out and incorrectness of this statement. It was also pointed out by Rathke (1830), Stannius (1846), Wiedersheim (1884), Gegenbaur (1894) and Haller (1904) that the tongue of fish consisted of the hyoid, i. e. the glossohyal and the mucous membrane which wrapped the glossohyal, and that no muscle existed. However, it was recently brought to light by Marcus (1934) that the tongue of *Polypterus* has what was known as the smooth muscle, which is a great step forward toward this line of study.

Since Oppel (1900) discovered that fishes had taste buds, this was reexamined by many anatomists. It was demonstrated by Herrick (1904) that the taste buds controlled their gustation not only morphologically but also neurologically. He found that they were governed by cranial nerves X and XII, and presumed the existence of their sense of taste. Furthermore, it is worthy of note that Aristotle described that some fishes had teeth which grew on the tongue. Very recently, Matsui (1936) studied morphologically and histologically the tongue of *Plecoglossus altivelis*, and made several discoveries in this direction.

Pharyngeal Teeth

The fact that the majority of fishes possess the teeth on the upper and lower pharyngeal bone, and those are the important masticatory organ, was made clear in the early part of the 19th century, by Jurin (1821) who studied the teeth of the Cyprinoid fishes. The study of the pharyngeal teeth of fishes was made in succession by Owen (1840–1845), Boas (1878), Ridewood (1896), and Tomes (1914) who was the greatest scholars on the study of the teeth of fishes, and made a remarkable progress in the line of study. Ridewood (1896) said that the development of the pharyngeal teeth and the jaw teeth were inversely proportional to one another; while Sagemehl (1885) took Scaridae as the material for study and said that the pharyngeal teeth were not only a masticatory organ but also an organ to ruminate food.

As a matter of fact, the development of the pharyngeal teeth is most apparent in Cyprinoid fishes, and because of the fact that their form and number have an important bearing in their classification, many scholars have engaged themselves in the study of the pharyngeal teeth of the fishes; namely, leaving alone Jurine (1821) whom I have already mentioned, Molin (1850), Hoppe (1894), Fack (1899), Gracianov (1900), Cerkasov (1903), Leonhardt (1903), Haempel (1907), Shepherd (1910–1914), Stoss (1921), Linden (1929); while very recently Chu (1935) completed his studies on the pharyngeal teeth of nearly all the fishes which belong to the Chinese Cyprinoid fishes, such as Leuciscinae, Chondrostomatinae, Abramidinae, Acheilognathinae, Hypophthalmichthyinae, Gobioninae, Cyprininae, and Schizothoracinae. Other than the pharyngeal teeth of Cyprinidae, those of Labridae were studied by Wright (1870) and Prince (1892), and those of Geridae by Sauvage (1876); while Schmidt (1913) studied those of Cyclopterinae.

As for the muscles that govern the pharyngeal teeth, Haempel (1908) made a study of those with the Cyprinoid fishes, and observed the M. pharyngo-arcualis, M. pharyngo-clavicularis externus, M. pharyngo-clavicularis internus, M. pharyngo-transversus, and the M. sterno-hyoideus, which were confirmed by Vetter (1874, 1878).

There is no one in our country who has made a special study of the pharyngeal teeth — only Hikita (1934), whom I have mentioned previously, gave a fairly detailed description of the pharyngeal teeth of the flatfishes of northern Japan in his report.

Gill-rakers

I believe that the first person who devoted himself to the study of the gill-rakers of fishes was Troschel (1849). He divided the gill-rakers into 2 parts, viz. the upper and lower part, from where the gill-arch curved, and studied their number, their thickness and their length. Šusta (1888) who was known for the study of carp culture, Walter (1903), and Steuer (1905) asserted that the thickness of gill-rakers determined the form and size of the food which they would catch, while Schiemenz (1905) taking for example the carp, etc., pointed out that fishes took various sorts of food according to the season and their needs, irrespective of the thickness of gill-rakers.

Zander (1903, 1906) was the most prominent among others who studied the gill-rakers. He observed in detail the form of the gill-rakers of Clupeidae, Salmonidae, and Cyprinidae and many other teleosts (even those of deep-sea fishes), and divided them into 2 main classes, that is, the perfectly developed gill-rakers and the degenerated ones. He went further to classify the perfect ones into 3 groups in accordance with their degree of development, and declared that the development of gill-rakers had close connection with the kind of food which they ate. Then, Rauther (1911) pointed out that the fishes which had the degenerated gill-rakers belonged to the families of Acipenseridae, Cyprinidae, Loricaridae and Syngnathidae.

Further, as the variation in the number of gill-rakers, their form and length have an important bearing on the classification of fishes; a great number of scholars have made a study of them. As for those of the shark, there is an interesting report written by Turner (1879) on the basking shark, which is noted for having a fine sieve. There are a few other reports too, but I shall omit them in view of their nature.

As the gill-rakers of sardine are so fine that they often attract the attention of scholars, considerable number of reports have been yet published. One of the most important recent reports was made by Scofield (1934) who observed the gill-rakers of *Sardina caerulea*, viz. the California sardine. And Sakô (1938), Nakai (1938) made the important reports on the gill-rakers of the Japanese sardine, *Sardinia melanosticta*, but as those reports will be explained in the subsequent chapter, I shall not mention their details here.

Digestive Tract

As for the general treatise on the digestive tract of fishes, I shall refrain from reviewing the work of Aristotle once too often, but let us look back upon the study made by Preston (1697) which I am inclined to believe to be the oldest. To quote his words "Their (fishes) stomach is membranous: for fish swallow down other small fish whole, and sometimes earth; therefore it is necessary to have a power of contracting itself forcibly to break in pieces its contents. Their intestines make several great windings, a sign that the fermentation is but slow in them, which is made up by their great length." After his work there is the report of Cavolini (1787), but I have not had a chance to read this.

Cuvier gave a very accurate account of the morphological studies he had made on the digestive tract of fishes in Vol. V of his "Leçons d'anatomie comparée" (1800–1805) and Vol. IV of "Vorlesungen über vergleichende Anatomie" (1809–1810), and the same of *Perca* in "Histoire naturelle des poissons" (1828). In the wake of Cuvier's contributions, Rudolphi (1802), Home (1814) and Meckel (1829), authorities on comparative anatomy, also studied the digestive tract of fishes; particularly Home and Meckel who concentrated their efforts to this study accomplished the valuable works with a number of fishes.

In studying the digestive tract of fishes we cannot forget the work of Rathke (1820–25). He was the first person to devote himself specifically to this study when the other scholars whom I have mentioned above, were studying it as a part of their work on comparative anatomy. He made a morphological study of the stomachs and intestines of *Gasterosteus spinchia*, *Cyprinus carassias*, *Silurus glaris* and 20 other species of fishes. Owen who is known as a great scholor of the comparative anatomy of teeth, made several original studies of the digestive tract of fish, one of which was completed in the year 1866. He was the person who classified the fish stomach into 2 types, viz. "siphonal" and "caecal". Among those who specialised in the digestive tract of teleost fishes, the work of Cajetan (1883) is widely known. He made a morphological study on the oesophagus, the stomach and the intestine of *Cobitis* and 5 other species of teleosts. And the anatomical works made by Cole (1901) on Pleuronectidae are also valuable for the person who study the digestive tracts of fishes. One of the great comparative anatomists, Gegenbaur made numerous contributions too in addition to his work in the year 1875. There are also many interesting articles regarding this study (particularly pertaining to those of the stomach) in the text-book of anatomy (p. 751–777) of Haller (1904). Then we come to the work of Eggeling (1908) who studied the digestive tract of *Pagrus*, *Sciaena*, *Scomber* and 40 other species of teleosts. Combining his studies with those of Cuvier, Rudolphi and Meckel, he completed a careful and detailed study of form and construction of the digestive tracts of 179 species of teleost fishes, especially the relation between the food and the folds of the mucous membrane of the digestive tract.

In studying the history of the digestive tract of fishes, the name of Eduard Jacobshagen and Eduard Pernkopf must be given as among the foremost.

In 1911, Jacobshagen wrote a treatise entitled "Untersuchungen über das Darmsystem der Fische und Dipnoer" which may be regarded as the most excellent report among those ever written on the digestive tracts of fishes, especially the winding type of the intestine and the folds of the mucous membrane. In doing this he made a careful study of the works of Cuvier, Home and Rathke and endeavoured to complete his studies in every way. There is, however, one thing which I think was unfortunate, and that is, all of his materials for study was taken from fishes in European waters. Nevertheless, in completing my present study, I am deeply indebted not only to his work but also impressed by the very earnest manner in which he pursued his study. In 1930, Pernkopf published a fine report entitled "Beiträge zur vergleichenden Anatomie des Vertebratenmagens". This report is not rich in its contents but it is evident therefrom that he possessed an infinite interest in the stomachs of fishes. He made a detailed study on the stomachs as also their mucous membranes, their muscles, and the pyloric appendages with number of fishes, and contributed immensely to this field of study. In Vol. II of the "Handbuch der vergleichenden Anatomie der Wirbeltiere" to which I have already referred in the earlier part of this treatise, he wrote about the stomach (Vorderdarm) and Jacobshagen about the intestine (Mittel- und Enddarm) and contributed to this line of study.

In regard to the form of the oesophagus of fishes, as this is generally studied concomitantly with the form of the stomach, there are no separate reports dealing with this subject alone. But there is a report by Bornaud (1887) dealing with the lining epithelium of the oesophagus of fishes, and Pictet (1909) made a report on that of Cyprinidae. Gerhardt (1914) wrote a report on the oesophageal papillae of *Ichthyococcus ovatus.*

Pernkopf's studies, above referred, can be said to be the most complete as far as form of the stomach of fishes are concerned, however, as already stated, there are still other studies such as of Cuvier or Jacobshagen. In Japan, Okamoto (1918) made a report on the form of the stomach of 47 species of Japanese fishes, but it was far from being satisfactory in that it decided the form of the stomach, in many instances, according to the results obtained from 1 fish only of each species. As for the structure of the stomach, I believe that what Aristotle said of the stomach of Mugilidae being like the structure of the gizzard of a bird and what Cuvier averred of Cyprinidae having no stomach (1810) are noteworthy remarks from a historical point of view. The stomachs of important fishes, such as the carp, the herring, the sardine, the salmon, the trout and the mullet, were made objects of study by many students, but insofar as literatures in this connection concerned, I shall mention them later. This is because of the way in which I should like to use them in my subsequent chapters.

The mucous membrane of the stomach has been observed by almost every students who has dealt with the stomach of fishes. But Oppel's (1896), Cuvier's, Eggeling's, Jacobshagen's, Okamoto's, and Pernkopf's with which names you are already familiar, as also Biedermann's (1875), Edinger's (1876) and Glinsky's (1883) works stand out above the rest.

Regarding the intestine of fishes, the studies of Jacobshagen, to whom I have already referred, surpass any those made. Among the numerous reports written in this connection, I should like to introduce here only the works which principally treated of the intestines of fishes and not those which anatomists have taken up as a part of their work on the comparative anatomy. First of all we have Preston (1697) whose report I am inclined to believe is the oldest. However, according to Günther's writing — " An introduction to the study of fishes ", 1880, p, 8 — Swammerdam (1637-1680) gave a description of the intestines of numerous fishes before this. The studies of Cuvier, Rudolphi, Home, Meckel, Rathke, Eggeling and Jacobshagen cannot be ignored by those who are interested in the study of the intestines of fishes, together with the important works of Gegenbaur on the general study of the same (1875, etc.).

There is a great deal of literature on the intestine of one species of fish, but as I shall have to mention them when I give an account of my own study, I shall refrain from mentioning them here, and in the present I shall introduce only the works which deal with the different families of fishes. Beginning with Clupeidae, Kishinouye (1907) wrote a short report on the intestines of Japanese sardines, while Krumbholz (1910) who made an anatomical comparison of the intestines of 10 species belonging to Macruridae, made mainly a careful observation of the winding type of intestines of these fishes. Nussbaum-Hilarowicz (1915) studied the form and structure of the intestines of 3 species of deep-sea fish, namely, *Stomias boa*, *Gastrostomus bairdii* and *Melamphaës mizolepis*. In 1923 Kishinouye made a brief report on his observation on the intestines of Scombridae. Not long after this Bühler (1930) made a morphological and histological study of the intestines of Stromatidae. Of the works in connection with the histological studies of the intestines of fishes in general, those of Valatour (1861), Oppel (1897) and Yung (1899) are excellent, while those of Pictet, whom I have mentioned are renowned too. He studied the histological construction of the intestines of 5 species of fishes belonging to Cyprinidae. There are also studies on the intestines of different species of teleosts by Blake (1930), and of fresh water fishes by Rogick (1931). With regard to the intestinal mucous membrane, besides the reports of Oppel, Eggeling, Jacobshagen and Edinger who dealt with this question when observing the stomach, the studies of Owen (1866) and Wiedersheim (1898) must be mentioned. Wiedersheim divided the folds of the intestinal mucous membrane into 4 types and related the relationship between them; while Eggeling pointed out that although the intestines of carnivorous fishes were short and those of the herbivorous long, their intestinal mucous membranes were promiscuously arranged and had no relationship with their feeding habits. Besides those whom I have already mentioned, those who engaged themselves in this study are Cattaneo (1900), Gemmill (1899), Bizzozero (1904) and Sunvick (1907) who also made a study of the intestinal muscles. Among the various studies on the intestinal mucous membrane, there is a rather interesting and novel report by Gulland (1898) on that of the salmon. He found out that at the time the salmon moved on towards the river from the sea, its intestinal mucous membrane underwent a catarrhal change, which change extended to its stomach, and when it had finished laying its eggs, it returned to its normal condition.

There are many other important researches, such as the works on the histological studies of the intestines of the loach which resorts to the intestinal respiration, and regarding the extensible stomach of fishes belonging to Chiasmodontidae or other deep-sea fishes, but as I shall be writing them later I shall not mention them in this chapter.

Pyloric Appendage

The pyloric appendage is a digestive organ peculiar to fishes, especially teleost fishes, and many of them have this organ. It is an appendage situated in bunches right after the pyloric part of the stomach at the beginning of the duodenum, and ranges in number from 1 to manifold. The first person to discover that fishes had a pyloric appendage was Aristotle. Though briefly he wrote about it in his book and stated that the number varied considerably.

Afterwards, a number of anatomists studied this organ and made reports concerning it, but up to the middle of the 19th century, none were able to observe correctly what this was. They had erroneously believed that it was the pancreas, or an organ to take the place of it. I believe that this misjudgement is traceable to 2 factors: firstly, because the pancreases of teleosts are diffused with the blood and lymphatic vessels and are not the compact organs as are seen in other vertebrates, and unless they are observed histologically, they are found with utmost difficulty. Secondly, because the teleosts have a pyloric appendage, an organ which cannot be found in other vertebrates. Such being the case, there is nothing to wonder that Preston wrote in his treatise (1697) " they have indeed usually many pancreases so that in some there have been found forty-four ", as even Cuvier, who is known as the father of modern anatomy, had made the similar mistake. To quote his words from Vol. I of his " Histoire naturelle des poissons " (1828) " C'est tout près du pylore, qu'il y a dans le grand nombre des poissons des boyaux aveugles souvent très nombreux, et dont la veloutée, repliée en mailles serrées, paraît fournir abondamment une liqueur glaireuse, que l'on croit avec vraisemblance tenir lieu de celle du pancréas ". Furthermore, Rathke, who specialised in the study of the digestive organs of fishes, reported in his well known " Über das Darmkanal der Fische " (1824) that the pyloric appendage and the pancreas were the same organ.

However, in 1873, Legouis made a study of the pancreases of numerous fishes and determined that the pyloric appendage and the pancreas were distinctly two separate organs, while Laguesse (1894) made a histological study of the pancreas and supported the statements of Legouis, which gradually dissolved the wrong idea hitherto maintained. Sometime after this Jacobshagen (1911) observed that the folds of the mucous membrane of the pyloric appendage were almost the same with those of the intestine, and Dawes (1929) made clear the similar article by the histological observation. Thus the fact that the pyloric appendage is an appendage of the intestine and the pancreas exists separately has became completely recognized.

Regardless of whether or not the pyloric appendage was mistaken for the pancreas, the study of the pyloric appendage and also its morphological observation, were made by Steller (1753) in the 18th century, letting alone Aristotle, and also by Hyrtl (1865, 1868) in the 19th century, and Kostanecki (1913) and Pernkopf (1930) in the 20th century, all of whom accomplished praiseworthy researches in this respect. Comparative anatomists too, like Stannius (1846, I, p. 197–198) and Owen (1866, I, p. 428) stated in their books in regard to the variation in the form and the number of the pyloric appendage and also its arrangement. There were others who engaged themselves in similar studies — such as Rosenthal (1824) who made these studies in connection with *Xiphias*, Kner (1851, 1852), Day (1887) and Cattaneo (1900) in connection with the Salmonidae.

Liver and Gall-bladder

Apart from the work of Aristotle, as far as I know, the oldest study which has ever been made of the livers of fishes was done in 1817 by Mierendorff, but unfortunately, I have not had an opportunity of reading this report. After his time, Rathke made reports on the structure of the liver of fishes in 1826 and 1838. In 1827, when Weber, renowned for his Weberian ossicles (or Weberian apparatus), was studing the liver of fishes, taking the carp for his material, he happened to discover, in such an old time, the hepatopancreas, an organ peculiar to Cyprinidae, and contributed much to the progress of the line of study. Some 50 years later, from 1866 to 1867, Eberth found out that the liver of teleosts was constructed purely tubulose and that the gall capillaries were finer when compared to those of other vertebrates. In connection with the study of the structure of fish liver, there are many works besides these, namely the study of Schmid (1882), the work of Macallum (1884) on the liver of *Amiurus catus*, the research of Shore and Jones (1889) who took the *Muraena* and *Pleuronectes* for their materials and found like Eberth that the liver of teleosts the tubulous structures. Opposing the study of Eberth, Retzius (1892) avouched that from the study he had made of the livers of *Esox* and *Anguilla*, the central capillaries of fish liver were in no way fine and that they, moreover, branched out in number.

Braus (1896) made a very interesting discovery when he was completing a comparative and anatomical study of the liver of vertebrates. He found that the liver cells of Selachii and Holocephalii were very large while those of Teleostomi were, on the contrary, very small.

In the 20th century, some studies were achieved by Segerstråle (1910) who had made a histological study of only the liver of teleosts. Quite recently, Siwe (1937) gave a morphological study on the fish liver, Vol. III, p. 739–742, of "Handbuch der vergleichenden Anatomie der Wirbeltiere". It is worthy of note that in his paper, he made the careful description on the position of the liver and its relation with the pancreas of such fishes as ***Anguilla vulgaris***, Pleuronectidae and other teleosts. There are many other studies, but as they do not deal with teleost fishes, I have decided to omit them.

Now we come to the development of the teleost liver. The studies of which were made by Stöhr (1893) and Stricker (1899). Stöhr undertook the study of *Trutta*, while, Stricker, in studying the development of the digestive system of the same species, was careful to note the connection between the position of the liver and that of the other organs.

In regard to the gall-bladder of fishes, the work accomplished by Aristotle is really remarkable. He began by explaining that fishes do have a gall-bladder and went on to discuss its form. The special study of the gall-bladder of fishes has seldom been made, viz., the report of Cabibbe (1903) is about the only one that has been written dealing with this subject. Unfortunately, I have not had a chance of reading this work as yet.

Pancreas

As the pancreases of higher vertebrates are all compact organs, they were correctly observed from ancient times, however, as the majority of those of fishes are diffused and not easy to discover them macroscopically, they were mistaken, as previously mentioned, for the pyloric appendages of fishes, before the middle of the 19th century.

The first person who ever attempted to write about the pancreas was Commelin (1667); then we have such men as Blasius (1673), Preston (1697), Cuvier (1828), Alessondrini (1833), Brockmann (1846), and Stannius (1848), but they have either erroneously taken the pyloric appendages for the pancreas or have commented upon the compact pancreases which can be seen in the Elasmobranch fishes. The influence of the mistake of a great anatomist like Cuvier was particularly great. Later, however, the wrong idea was rectified by Legouis (1873). He discovered the scattered, diffused and compact pancreases of fishes, and declared that they were entirely independent of the pyloric appendage. In spite of his research was minute and eminent in every respect, he was unable to clarify the mistake hitherto maintained in its entirety because he had observed the pancreases of fishes histologically or embryologically. Not long after this, Kruckenberg (1877), by physiological experiments of the pancreases of *Belone rostrata*, *Rhombus maximus*, *Mugil cephalus* and *Perca fluviatilis*, was able to ascertain for himself that fishes have a pancreas. But, he received the objection of Nussbaum (1882) and Cajetan (1885), and his study were also not yet recognized generally. Then, with the advent of Laguesse (1889), who took it upon himself to reexamine both histologically and embryologically the pancreases of Crenilabridae, Scorpaenidae, Blennidae and Syngnathidae, the same fishes which Legouis had observed macroscopically, and advocated the precision of Legouis's research, thus the mistake which hitherto prevailed was retrieved. Later, with the discovery of the pancreas cell by Eberth and Müller (1892) of *Esox lucius*, the fish pancreas became to be better known and the knowledge thereof more accurate.

Kupffer (1892) studied the development of pancreases and spleens of teleosts; Göppert (1893) the development of the pancreas of *Trutta fario;* Krüger (1904) the histology and physiology of those of *Perca fluviatilis, Cottus scorpius,* and 10 other species of teleosts; while Woodland (1911) studied the gas glands of teleosts and their pancreases at the same time, thus making it possible to understand what the pancreas really is.

In the meantime, Diamare (1899) was able to prove histologically with *Lophius piscatorius* and 7 other species of fishes that the so-called corpuscle which Brockmann and Stannius had written, were of the same construction as the islets of Langerhans of higher vertebrates. Not long after this Rennie (1913) made a report of the studies on which he had made of *Lophius piscatorius* and 27 other species of teleosts and reported that there were islets of Langerhans which were both isolated and scattered, whereupon Vincent and Thompson (1907) proved that the islets of Langerhans of fishes produced insulin like those of other vertebrates, and contributed materially to the line of study. There is a report of great significance written recently by Siwe (1926) dealing with the development of pancreas in the embryos of *Trutta, Cyprinus, Coregonus,* and *Syngnathus.*

In Japan the study of the pancreas of fishes has been achieved — in fact it was brought to the attention of the people concerned when Ôsawa (1915) discovered that the pancreas of *Limanda Yokonamae* was scattered around its bile duct and that there was 1 islet of Langerhans. Ugai (1926) made a histological observation of the pancreases of 23 species of fishes, particularly of Brockmann's corpuscles. Recently, Arima and Kubota (1931) finished a very detailed and thorough study of the pancreases of fishes living in fresh and sea waters, and found that the pancreases of a total of 72 species were distributed inside and outside of the liver, outside of the digestive tract, and inside of the spleen.

FOOD AND FEEDING HABITS

Preamble

The study of the food and the feeding habits of fishes may be divided into 3 sections: —

1. Baits for angling.
2. Baits for fish culture.
3. Natural food.

With regard to the first item, the angling is an occupation of old historical standing, consequently it has been studied from ancient times. Regarding the second item, the carp, for example, which has been cultured from ancient times, its baits have been noticed from very olden times. But as the study of the third item became necessary for study only after the fish anatomy was put in practice and the result of the first and the second items were properly systematized, so the history of this study is comparatively young.

Now, as the first and the second items do not, on the whole, have any connection with my present study, I wish to concentrate my efforts on the third item and make a comparatively detailed explanation to its history of study.

The scientific papers in connection with the study of the natural food and the feeding habits of various fishes in various countries throughout the world run into a great number, with the works of Aristotle before Christ and Collinson (1746) in the 18th century heading the list. In this chapter, however, I wish to mention mainly those which handle the subject synthetically, and those pertaining to the food and feeding habits of one species of fish will be taken up later when I write about the studies which I made personally, referring to them as literature consulted. I shall not therefore mention them here, unless they require special mention or unless I think I do not have a chance of mentioning them later.

General Treatise

In order to understand the feeding habits of fish correctly, one must, even for the study of 1 species of fish, make a careful examination of the stomach contents of the numerous fishes collected in different localities each season, and it is only after this that one is able to form an opinion. It is therefore almost impossible for any one from the standpoints of time and economy to complete this work, viz. strictly speaking, the study of the food and feeding habits of fish. No one has therefore completed this difficult task to this day. However, in gross estimation, there are quite a number of valuable reports written on the general treatise of the food and feeding habits of fish.

First, Forbes (1878, 1880) studied the feeding habits of various fishes living in the fresh water regions of Illinois. Although this is a rather old study and confined to one district, it is an important study for students in that 1) the study was made from a wide range of material, and 2) an excellent classification was made of the feeding habits according to the results of the study. He examined the natural food of *Dorosoma cepidianum*, *Polyodon spathula*, *Ameiurus melas*, *Catostomus nigricans*, and a few others, all of which are fresh water fishes, and classified their feeding habits into 8 classes, namely, mud eaters, plankton eaters, shell-fish eaters, insectivores, vegetarians, piscivores, dead body eaters and omnivores. He stated further that the digestive system of each group of fish and their feeding habits had close relation to each other.

There are quite a few text and popular books on the feeding habits of fishes, but the majority of them are more or less conceptive and based upon poorly-founded scientific grounds. But owing to the information in the books written by Leunis (1883) and Brehm (1892) regarding the feeding habits of fishes being accurate and written in detail, students have used them in their scientific papers. For example, Eggeling (1907), when making a report of his studies on the digestive tract of fishes, adopted the studies of the former for every species of fish and contrast them with his own. Šusta (1880) who studied the feeding habits of carp and many other fresh-water fishes, gave examples of the voracious carnivores the *Esox lucius*, *Perca fluviatilis*, *Silurus glanis*, *Anguilla vulgaris*, and 4 other species; as small animal eaters, the

Carassius vulgaris, *Gobio fluviatilis*, *Cobitis fossilis*, *Coregonus maraena*, and 8 others; as herbivores, the *Scardinius erythrophthalmus*, *Leuciscus rutilus*, *Squalius dobula*. Pearse (1915), as the results of his examination of the food of numerous fresh-water fishes living in lakes and marshes in the State of Wisconsin over a period of 2 years, from 1914 to 1916, stated that although the food taken by fishes in the same habitat was almost the same, there was a certain amount of preference, according to the species of fish. He classifed these fishes into 5 classes in accordance with their feeding habits, namely, vegetarians, piscivores, insectivores, those that eat entomostracans, and those that eat mud and sediments.

Besides the reports mentioned above, there is a report by Knox (1855) on the food of certain gregarious fishes, and a few others by Baird (1871), Sim (1883), Goode (1883), Robertson (1890), Carr (1908), who treated the subject of fish food in a rather conceptional manner. Most of these reports are short, and although they are taken up from a historical point of view, they are not important.

In Japan, Tokuhisa (1918) was one of the first to write a general treatise on the feeding habits of fishes. He examined the stomach contents of 25 fishes collected in the fresh and brackish water of Lake Hamana, Kasumigaura, Lake Biwa and Imaenada, and rectified the classification which Forbes had made. He classified them into 7 classes, viz. piscivores, shrimp-eaters, insectivores, shell-fish eaters, plankton eaters, algae eaters and mud eaters, and drew attention to the fact that there were fishes of one species which entering under 2 or 3 classes. S. Nakamura (1932–1935) made a very important and interesting report on the feeding habits of various fishes cultured in the aquarium of Kominato, Tiba Prefecture.

Food of Fishes in Various Localities

As the natural food of fishes in fresh-water regions is an important matter, not only from angling point of view but from the transplantation of fishes, a great deal has been written about it in the past.

To begin with, Forbes, Šusta, Pearse and Tokuhisa studied the food of fresh-water fishes; besides which, the study made by Schiemenz (1905) is important historically. He examined the stomach contents of *Leuciscus rutilus* and a few other important wild fishes living in fresh-water and pointed out that their food consisted principally of insect-larvae or plankton, such as the copepods and the diatoms. Then, we have the report of Dröscher (1907) which we cannot overlook. He, like Schiemenz, made a study of the feeding habits of almost the same fresh-water wild fishes, and compared his study with those of Schiemenz and others. Insofar as the general remarks are concerned, he was inclined to agree with those of Schiemenz and others. For studies made recently, Dobers (1922) must be mentioned. Since 1913 he engaged himself in the examination of the stomach contents of 4 species of fresh-water fishes in the experimental pond of Sachsenhausen, Germany. They were *Perca fluviatilis*, *Acerina cernua*, *Leuciscus rutilus*, etc. As the result of a very close examination of the stomach contents of these fishes, he found that they ate principally the larvae of *Chironomus* and others, *Bosmina* and *Daphnia*, etc. Sibley (1928) examined the stomach contents of a great number of fishes in Lake Erie, America, and ascertained that larval fish was the staple food of adult fishes in this region, and that the larvae of Chironomidae and insects came next. He also found that the food of larval fishes was planktonic crustaceans.

In addition to these reports, there are others by Strodtmann (1897) who studied the natural food taken by various fishes for instance, *Leuciscus rutilus* and other fishes, in the fresh-water regions of Germany; by Ward (1898, 1903) who studied the food of fishes in Nebraska Stream and Lake of the Sierras, America; by Hankinson (1908) who examined the food of fishes in Walnut Lake; by Lavrov (1909) who observed the food of those in the Wolga River, Russia; and by Kemmerer, Bovard and Boorman (1923–24) who studied the food of those in Bear Lake, Henry Lake and other lakes in America. Roughly speaking. the contents of these reports are more or less along the same line as those already given.

In Japan, besides the excellent report written by Tokuhisa, there is an interesting report by Kondô (1929). When he was making a study of the influence the dirty water of the tributaries entering into the Yodo River had on the creatures living in that region, he discovered, as the result of examining the contents of the digestive tracts of *Sarcocheilichthys variegatus*, *Opsariichthys uncirostris*, *Carassius auratus*, *Cyprinus carpio* found in the Katura River, that the fishes living there were bigger and plumper in comparison with those in other regions, and that this was because dirty water helped the increase of the larvae of Chironomidae, etc., the staple food of fishes in that region, rather than hindered it.

In the reports written by Takayasu, Igarasi and Sawa (1930) of the Hokkaidô Fisheries Experimental Station regarding the biological investigations made of the various lakes in the Hokkaidô, there is a record in connection with the natural food of various fishes, *Triborodon hakonensis* and others, in the lakes. This record gives valuable hints in utilizing the above lakes. Furthermore, the Imperial Fisheries Experimental Station (1935) made a biological investigation of Lake Aoki, Nagano Prefecture. During this investigation, they made a minute investigation of seasonal variations in the natural food of *Triborodon hakonensis* and *Hypomesus olidus*. Seiisi (1935) examined the stomach contents of *Triborodon hakonensis* and a few other species at the water-way of the Yamaguti Reservoir and rendered valuable hints insofar as the purification of the source was concerned.

The study of the natural food of sea fishes is regarded with importance for fisheries, because it has a close connection with the distribution and migration of these fishes. It was for this reason that a great number of reports, as given hereunder, were published.

Let us begin with the works of German scholars: Möbius (1875) studied the natural food of North Sea fishes; Rauschemplat (1901) of fishes caught in Kiel Bay; Franz (1910) of North Sea fishes; Schultz (1911) of those in the

Baltic Sea. He also studied the parasites at the same time he was studying the stomach contents. Of these reports, Franz's report is noted for its completeness. He analyzed in detail the stomach contents of *Gadus morrhua* and 7 other species of Gadidae, *Pleuronectes limanda* and 1 other species of Pleuronectidae. Lately (from 1928 to 1929) Hertling wrote a report on the natural food of Pleuronectidae and many other sea fishes in the Baltic Sea. This too was a very fine piece of work.

In England, there are the reports of Day (1882), a noted ichthyologist, who examined the stomach contents of herrings and mackerels in Cornwall; Smith (1891, 1892); A. Scott (1896); and T. Scott (1902, 1903). Of these Scott, although I shall write about it later, directed his studies not only to the food of adult fishes but to young fishes as well. In addition to these reports, there is a report regarding the molluscs, etc. playing an important part in the food of fishes by Todd (1900-1905); as also reports by Johnstone (1906) and Carr (1908) who examined the stomach contents of various fishes in English waters. When the Imperial Oceanographic Institute of Russia conducted in 1929 experiments of the Barents Sea fisheries, Zenkevich (1931) studied both seasonally and quantatively the stomach contents of the cod and other fishes, and made a very important report on the food constitution of each fish. Besides this report, I should like to mention the recent work of Birula (1934) which deals with the food of blackish and sea-water fishes of the Kara Bay and Kara River.

In 1929 the Muroran Branch of the Hokkaidô Fisheries Experimental Station in Japan conducted some fishing experiments at various places using the deep-sea tow-net, at which time they examined the stomach contents of the fishes belonging to Scorpaenidae and Macruridae and other various species. These experiments went a long way towards clarifying the natural history of deep-sea fishes and developing deep-sea fishing grounds.

The connection between the living conditions of bottom faunas and those of bottom fishes, especially their food, has very often been brought up for contrast. Denmark is noted for her studies in this direction. Among her scholars Petersen (1911, 1918) and Blegvad (1925) are the most noted. In England the studies of Ray (1913) who said that the bottom deposits of the Irish Sea had close connection with the stomach contents of bottom fishes and Steven (1929) who made practically the same remarks about fishes around Plymouth, are the most distinguished. At the same time he was examining the bottom faunas living there, Steven studied the stomach contents of flatfishes and gurnards living in the same region and discussed not only the close relationship existing between the two but made a careful and detailed observation of the interesting feeding habits of the various species of bottom fishes.

Thus, as can be seen from the foregoing, there is quite a bit of literature on the food of bottom fishes, but everyone of them deals only with the food of fishes on the shallow-sea bottom, and there is hardly any one to study the same on the deep-sea bottom. It is, however, just touched upon in the papers of Gill (1878), Goode, and Bean (1895) where they say that *Chiasmodon niger* has an extensible stomach and swallows large size fishes whole.

The report of Joubin (1933), of France, written at a time when there was such a scarcity of literature on this subject, was a great incentive to the scientific world. According to his researches, deep-sea bottom fishes (not only fishes but also other animals) live, so to speak, on some jelly-like substance which has been produced by the decomposition of bacteria of dead bodies of animals and vegetables, which had died in shallow seas or rivers, and by the pressure of water upon them after they had been brought to the deep-sea bottom after many years, and the view hitherto advocated that they ate one another was not correct in many instances.

Plankton and Food of Fishes

It was after the middle of the 19th century when the study of the plankton became so systematized that it became to be considered as an important food of fishes, either directly or indirectly.

The first person to study the plankton as an important natural food of fresh-water fishes was Baird (1857). He made a microscopic examination of the stomach contents of the trout and a few other species of fresh-water fishes and found that they consisted mainly of the plankton. After this, Forbes (1880, 1883, 1888, 1914), Šusta (1888), Schiemenz (1905), Dobers (1922), and Sibley (1928) studied the food of fresh-water fishes. The majority of scholars agree that the plankton plays an important part in the food of fishes. Of the many reports written about the food of fresh-water fishes, the report of Zacharias (1893, 1902) is perhaps the most prominent historically. Scientists who discuss to any extent the connection between the plankton and the food of fishes cannot of necessity neglect this report. He examined the stomach contents of *Coregonus albula* and *Perca fluviatilis* etc. found in Plön Lake, principally young fishes of these species, and emphasized the importance of the plankton as fish food.

Recently, Ladiges (1935) examined the stomach contents of fishes at the mouth of the Elbe River and found that copepods were their staple food. That the plankton is an important food of marine fishes is discussed in the reports of Verrill (1871), Möbius (1881, 1882), Dunn (1885), Fulton (1889), Brooke (1893), Hofer (1896), Steuer (1905) and Frank (1905). As marine fishes that take the plankton directly as their main food are chiefly sardines, herrings and mackerels, fishes which are valuable world-wide for fishery, there are ever so many excellent reports about them, such as those of Lewis (1929) on the sardine (*Sardina caerulea*); Savage (1931) on the herring (*Clupea harengus*); and Bullen (1908) on the mackerel (*Scomber scombrus*). However, I shall not go into details at the present chapter, as I shall write about them later.

Besides the foregoing, recently an American botanist, Lowe (1936), made a study of the Pacific diatoms and came to a very interesting conclusion that diatoms were the food of copepods; copepods the staple food of herrings; and herrings, in many instances, became the food of larger fishes; and that, to quote his words: "The copepods and herring were found to be important links in the food chain between diatoms and the large fishes." These remarks are, however, neither new nor original, as in 1908 Johnstone wrote already about the connection in his book, p. 286, or since long every biologist and even layman know it well as a common sense.

One other thing that I must mention regarding the plankton as fish food is about the book written by Cornish (1896) entitled "Animals at Work and Play; their Activity and Emotion" dealing with the oecology of various animals, in which on pages 240–247, under the caption of "The Invisible Food of Fishes", he emphasized the zoo-plankton and phyto-plankton as important fish foods. This article, at a time when the knowledge of the plankton was not quite so popularized, must have aroused the interest of many an amateur scientist.

As for studies on fish food by Japanese scientists, besides those already mentioned, Kishinouye (1907) wrote a report on the plankton as seen in the stomach of Japanese sardines (*Clupea melanosticta*), while Tokuhisa (1908) wrote a report on diatoms eaten by *Plecoglossus altivelis* in the Tama River; Nakazawa (1921) on the feeding habits of *Sardinia melanosticta*, *Clupea pallasii*, *Engraulis japonicus*, *Clupanodon punctatus*, *Cololabis saira*, *Trachurus japonicus* as fishes that eat the plankton; and T. Miyauti (1935) on the food of *Hypomesus olidus* found in the waters of Kasumigaura.

Food of Young Fishes

In the previous chapter, I have written about the importance of the plankton as the main food of fresh-water and marine fishes, such as herrings and sardines. In the present chapter I wish to explain the plankton, by citing references, as something more important as the natural food of practically all larval or young fishes.

With regard to the food of young fishes living in fresh-water, besides Zacharias who pointed out in his report of 1901 and other similar reports that the plankton was an important item in the food of young fishes, recently Sibley in his report of 1928 asserted that the food of larval fishes in Lake Erie, U. S. A., was practically confined to planktonic Crustacea.

In connection with young marine fishes that take the plankton for their food, Herdman (1893), Scott (1907) and Allen (1917) reported on various young fishes, while Petersen (1897) made a detailed report on the young of Pleuronectidae, but the study by Lebour is the most renown of all the researches made on the food of young fishes. As the result of her observations in 1917 of the stomach contents of *Labrus bergylata*, *Caranx trachurus*, *Scomber scombrus*, and various other post-larval fishes caught in tow-nets off Plymouth Sound, she found that their main food was copepods (1918). Further in 1919 she examined the stomach contents of *Labrus bergylata*, 17 species of young fishes and 41 species of post-larval fishes and ascertained that they consisted of such species of the plankton as diatoms, copepods, schizopods, flagellates etc. In the same year she made a list of the species of the plankton which became the food of young fishes and made a report on the species of fishes that ate these.

Later, Welsh and Breder (1924) studied the life history of white perches, spots, and croakers collected along the coast of eastern United States and paid careful attention to the food of their young. Pearson (1929) also paid particular attention to the stomach contents of young fishes when he was studying the life history of redfishes and croakers, principally the fishes which belong to Sciaenidae collected along the coast of Texas.

Not long after this Hildebrand and Cable (1930) studied the life history and development of 14 species of teleostean fishes collected in Beanfort and made a careful observation of the natural food of anchovies (*Anchoviella epsetus, Anch. mitchilli*), pig fishes (*Orthopristis chrysopterus*), white perches (*Bairdiella chrysura*), spots (*Leiostomus xanthurus*), croakers, (*Micropogon undulatus*), amberfishes (*Seriola dumerili*). and summer flounders (*Paralichthys dentatus*).

In Japan Nakazawa (1921) stated that the food of young fishes was the plankton and advocated the fact that it was very important to make a study of this as far as fishery was concerned. Uchida who is noted for his work on the life history of Japanese fishes, found from his observation of the food of *Oplegnathus fasciatus* (1926), *Monacanthus cirrhifer* (1927), *Parapristipoma trilineatum* (1929), *Hyporhamphus sajori* (1930), *Pleuronichthys cornutus* (1932), *Siganus fuscesens, Pempheris umbrus* (1933), *Verasper varegatus, Boleophthalmus pectinirostris* (1935), and *Coreoperca herzi* (1935) that during their young stage their food was the plankton, either copepods, other minute crustaceans or diatoms.

From 1936 to 1938 Okada and Seiishi investigated the development and ecology of various Japanese fresh-water young fishes. In this study they analyzed the stomach contents of *Pseudorasbora parva*, etc. (1936) *Pseudobogrus aurantiacus* etc. (1937), *Cobitis biwae* (1938), and *Tribolodon hakonensis*, etc. (1939), and found that small insect larvae and aquatic algae played an important part in their food, not to speak of the primary importance of the plankton.

Voracity of Fishes

The fact that fishes have their stomach filled with food — in other words, the voracity of fishes — has attracted the attention of people long before the various items I have already mentioned were ever discussed, due to the fact that there were opportunities for experts or specialists, such as fishermen, anglers and chefs to observe them more frequently. For example, Arnault de Nobleville stated in 1756 in his book that pikes were extremely voracious.

Now, I can easily give the names of these reports in their chronological order, but as I believe that it will be easier to understand if I gave them according to the classification of fishes I shall do so.

There are various reports, besides the report of Adams (1848), on the voracity of certain species of sharks which say that they had even made man the target of their food, but as this is not within the scope of my present studies, I shall omit them. Moreover, as I have related in the chapter of the "Digestive System" that the sword-fish used its sharp jaws to attack whales and other large animals (including human beings), I shall not make any comments about it again in this chapter.

Steele (1876) wrote about the voracity of the cat-fish belonging to Siluridae. According to his report there was some ox liver, 23 pcs. of hen's eggs, and a child's shoe in the stomach of the cat-fish caught in the lake on the Arkansas.

The gar-pike, *Lepidosteus*, with projected lower jaws is commonly found in the Mississippi Valley. Regarding the avidity of the pike, *Esox lucius*, as already stated, Arnault de Nobleville (1756) was the first scholar to write about this. Then, Stirling (1863) and Corbin (1873) made reports on the voracity of this fish. According to Stirling, the above fish attacked water-hens and water-onzels, from which it may be seen that the voracity of this fish was no less sharper than the greediness of fishes about which I have already written.

Everyone knows that the cod-fish is voracious. Buckland (1876) found 10 different kinds of fishing hooks and a piece of fishing cord in the stomach of an English cod-fish and inferred that it took more than 10 species of large fishes at one time, and was utterly amazed at its greediness. Trachmann (1889) found that one *Gadus aeglefinus* had stuffed its stomach with 14 *Gadus merlangus*; Sharp (1901) described the avidity of the Englich cod which greedily gorged bottom-creatures, such as crabs and shell-fishes; Marukawa (1919) reported on the gluttony of the Japanese cod-fish, *Gadus macrocephalus* — how it gorged *Theragra chalcogramma*, flat fishes, trouts, crustaceans etc.; Hickling (1928) on how the *Merluccius vulgaris* fed on the *Gadus poutassou*; and all the scholars agreed with the opinion expressed on the voracity of the cod.

The angler-fish is a grotesque looking fish with a very big mouth. For this it was included unconditionally with the voracious fishes. Besides Blake-Knox (1865) who said that the angler fish, *Lophius piscatorius*, was a ravenous fish. Fulton (1903) asserted not only the voracity of this fish but owed the frequency of an empty stomach to the complete digestion of the food with which it had filled its stomach during the time it had been allowed to lie after it was caught. Regan (1930) intimated that angler-fishes of the deep-sea took all the food they could once they found it, for they were always in want of food. To support his statement, he described the largeness of its stomach and proportionate expansion, and gave an example of a certain angler fish which he had examined. This fish swallowed whole a fish 2 to 3 times its size. Contrary to this, Tanaka (1916) and Wilson (1937) advocated the fact that the reason the buccal cavity and stomach of angler-fishes caught by trawlers were filled with fish was because they had taken food while they were in the trawl or it was forced in accidentally while they were knocking about in the trawl, and negated the voracity of angler-fishes, which is worthy of note.

It was observed by Carte (1866), Günther (1866), Gill (1879), and Goode and Bean together (1895; Fig. 264; no description) that the black swallower, *Chiasmodon niger*, had a distensible body and stomach and could swallow fishes many times its own size. Gill wrote as follows regarding the manner in which it seized its prey: "It espies a fish many times larger than itself, but which, nevertheless, may be managed, it darts upon it, seizes it by the tail and gradually climbs over it with its jaws, first using one and then the other; as the captive is taken in the stomach and integuments stretch out, and at last the entire fish is passed through the mouth and into the stomach, and the distended belly appears as a great bag, projecting out far backwards and forwards, over which is the swallower with the ventrals dislocated and far away from their normal place. The walls of the stomach and belly have been so stretched that they are transparent, and the species of the fish can be discerned within",

Curious Feeding Habits of Fishes

In some text-books or popular books of fishes, there is an interesting article on the curious feeding habits of the archer-fish (*Toxtes jaculator*) and a few others. However, as the source from which the information had been derived was not clear, there were many people who did not give credence to it. I myself was one of them too, but after making a thorough investigation of the literature on this subject,, I found that there were not only a great deal of them but many reported results of observations that were really reliable. I have therefore decided to make a few remarks under this caption.

The archer-fish or the shooting fish, viz. *Toxtes jaculator*, has a peculiar habit of catching and eating insects near the surface of the water by shooting drops of water at them. This was first described by Schlosser in 1764. The following is an extract from his report, and it is, in my opinion, a valuable piece of information in that it describes the results of his experiments: —

"Governor Hommel gives the following account of the jaculator or shooting fish, a name alluding to its nature. It frequents the shores and sides of the sea and rivers in search of food. When it spies a fly sitting on the plants that grow in shallow water, it swims on to the distance of 4, 5, or 6 feet, and then, with a surprising dexterity, it ejects out of its tubular-mouth a single drop of water, which never fails striking the fly into the sea, when it soon becomes its prey. The account of this uncommon action of this cunning fish raised the Governor's curiosity; though it come well attested, yet he was determined, if possible, to be convinced of the truths, by ocular demonstration. For that purpose he ordered a large wide tun to be filled with sea water; then had some of these fish caught and put into it, which was changed every other day. In a while they seemed reconciled to their confinement; then he determined to try the experiment. A slender stick with a fly pinned on at its end was placed in such a direction, on the side of the vessel, as the fish could strike it. It was with inexpressible delight that he daily saw these fish exercising their skill in shooting at the fly with an amazing velocity, and they never missed the mark".

Governor Hommel referred to in the quotation gave an account of his observations. The following is a part of his report: —

"When the jaculator fish intends to catch a fly or any other insect, which is seen at a distance, it approaches very slowly and cautiously and comes as much as possible perpendicularly under the object: then the body being put in an oblique situation, and the mouth and eyes being near the surface of the water, the jaculator stays a moment quite immovable, having its eyes directly fixed on the insect, and then begins to shoot, without ever showing its mouth above the surface of the water, out of which the single drop, shot at the object, seems to rise ".

There is also an interesting report on the experimental results of this fish in Brehm's "Tierleben". There is described how archer-fishes cultured in an aquarium began to shoot water as they became accustomed to their environment, and how the shooting was directed not only to ants and insects crawling on the walls of the aquarium but to fingers that were brought near the vessel.

It will be seen from the foregoing, I think, that this fish had a curious way of getting food, that is, by shooting water at insects or any other object that was to be its food. In addition to these studies, Zolotniskii (1902) observed the shooting of the fish cultured in an aquarium and Beccari (1904) in Sarawak, Borneo. Recently Dobben (1935) cultured this fish in an aquarium and found that its shooting distance was from 30 to 40 centimeters. In 1936 Wegner examined the construction of its mouth anatomically and studied its functions.

It is a well known fact that the walking goby or the jumping fish, *Periophthalmus*, which inhabit the tropical waters of Africa, Asia and Australia, not only have the odd habit of coming ashore but climbs trees as well. In this connection, vide the works of D. Livingstone and C. Livingstone (1866), Bean (1889), Woodford (1890), Jordan, and Seale (1905). According to Hickson (1889) who studied the habits of this fish in Celebes, it favours and eats not only the crabs and insects in the water but those on land. The Japanese *Periophthalmus*, that is, the Tobihaze (*Periophthalmus cantonensis*), whose habitat is in the Ariake Sea and other regions, feed on, according to Uchida (1935), small animals, such as little crabs and worms along its shores.

Saemundsson (1922) stated that the fry of *Ceratias*, one of the species of the angler-fish, lived on the skin of its large female as parasites. Later it was developed by Regan (1930) that the small fry which Saemundsson had seen was really an adult male, and that when it was compared with the female, it was one thousandth its weight and hung on to the skin of the female by its mouth. It was also revealed that their blood vessels were ultimately joined, and that the male obtained its nutrition from the female.

Furthermore, there are various other literature on the curious feeding habits of fishes, such as *Fierasfer* which makes its way into the cloacal chamber of Holothuiroidea, and the shark suckers (Echeneididae) which attach themselves to the body of sharks and take whatever food that is left over by them. However, I shall not go into details regarding them. Before concluding this chapter I should like to introduce the very characteristic work of Moodie (1909). According to his investigations, the chub (*Semotilus atromaculatus*) a fish which has its habitat up the Niobrasa River in North America, jumps up and seizes the horn flies (*Haematobia serrata*) that swarm around the oxen that are raised in this region and bathe in the river in the summer. He took a photograph of this and produced it in his report.

Miscellaneous

I have in the foregoing chapters given under different headings an outline of the history of the studies made in connection with the feeding habits of fishes, and believe that I have convered the ground fairly well, but as there are a few other articles which cannot be included in any of the chapters already given, I will introduce them collectively in this chapter.

It is a matter of common knowlege that a species of mosquitoes in the tropic called *Anopheles* is the intermediary of malaria. As it is important to study and know to what extent the minnow and other fresh-water fishes feed on the larvae of this mosquito and thus to what extent they are the means of eliminating malaria, scholars of different nations have engaged themselves earnestly in this study. However, as the germs of this disease, viz. *Malaria plasmodium*, were discovered in 1880, it was only in the 20th century that this study became to be taken up seriously. The oldest report in this respect was made by Mark (1890). Some thirty or forty scientific reports were later submitted by scholars of different countries, but the most noted of these are, I believe, the report of Seymour-Sewell and Chandhuri (1912) and that made by Hilderbrand (1919, 1921).

When Seymour-Sewell and Chandhuri were studying the efficaciousness of fishes as mosquito destroyers, taking for their material various Indian fishes, in view of their feeding habits, they found that *Haplochilus panchax*, *H. lineolatus*, *H. melastigma* which belong to Cyprinodontidae, were useful as destroyers of the mosquito larvae, because they had a habit of getting their food near the surface of the water and were strong enough for transplantation, and that *Barbus phuntunio*, *B. stigma*, *B. ticto*, *B. terio* and *Nurio danrica*, which belong to Cyprinidae, were also useful, judging from their feeding habits for similar purposes. Hildebrand found that the *Gambusia affinis* in his aquarium ate more than 100 mosquito larvae per day, and recommended that the fish would also be a useful mosquito destroyer. He ascertained at the same time that *Heterandria formosa* was efficacious too in this respect.

In Japan Koizumi (1914) and Miyazima, Koizumi and Takano (1925) made similar studies and found that *Rasbora daniconia* was also useful which was thought useless by Seymour-Sewell.

Miura is one of the famous divers of Japan, and his report on the ecology of aquatics at the bottom of the sea is very interesting and noted for its interest. He wrote a number of articles on the living conditions of fishes, among which the one on feeding is most interesting. For instance, regarding what he calls the "sand-blowing" fishes, i. e., *Monacanthus cirrhifer* and *Ditrema temmincki*, etc., he said that these fishes shot water which they had in their mouth by suddenly shutting the opercles to blow the sand away from their food which consisted of worms, small crabs and fishes which have their habitat in the sand at the bottom of the sea.

In conclusion, I wish to say a few words on the famous Pütter's theory:

the very attractive theory advocated by Pütter in the year 1909 on the mode of taking nourishments by fishes. He maintained that fishes, especially young fishes, absorbed organic and inorganic substances not only through their gill-filaments or alimentary canals but also their skin. As this was a very original way of thinking, it was questioned at the time, but later Lipschutz (1911) made experiments with carps and eels and supported his idea.

Systematic Survey

REMARKS ON DESCRIPTION AND ABBREVIATIONS USED IN THE FIGURES.

I. Abbreviations used in Description.

1) Mouth. "m-c" and "m-b" are the abbreviations used for cleft of mouth and breadth of mouth respectively.

2) Tongue. Looking at it from above, I have used the words "triangular", "trianguloid", "semi-elliptic" and "long-stretched" as the form may be. For special forms, I have given illustrations.

3) Pharyngeal teeth. In the majority of cases, I have described the teeth on the upper and lower pharyngeal bones separately. And as the teeth on the upper pharyngeal bone are generally divided into 3 sets, namely, the front, the middle and the back sets, an necessity arose, I showed the number of teeth of the respective sets as I-av. 12, II-av. 20, and III-av. 10.

4) Gill-rakers. All descriptions are made of the gill-rakers on the first gill-arch (left side). When I say that the gill-rakers are correspondingly "vertical" or "oblique" to the gill-arch, I am referring, as illustrated, to the angle between the base line of the gill-raker and the long axis of the gill-arch.

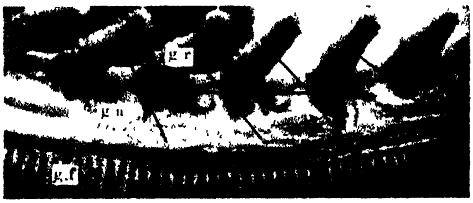


Fig. 7. Angle of gill-raker.

5) Stomach. According to its

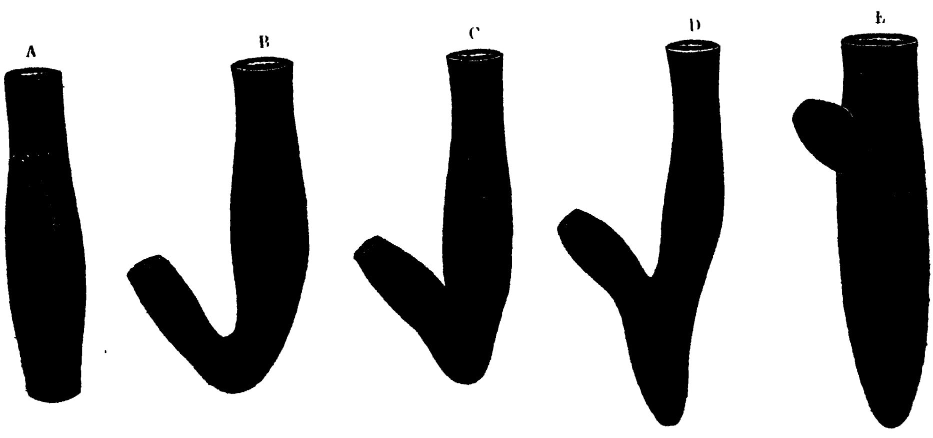


Fig. 8. Shape of stomach. A. I-shape. B. U-shape. C. V-shape. D. Y-shape. E. ⊣-shape.

outward appearance, the terms "I-shape", "U-shape", "V-shape", "Y-shape", and "┤-shape" are used.

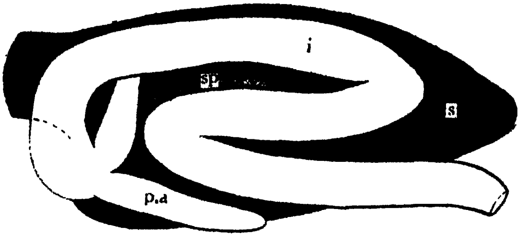


Fig. 9. N-form winding.

6) Intestine. In many instances the intestine is described as being "N-shape". By this I mean, as shown in the illustration, the intestinal tract which makes a turning of nearly 360° twice. When excluding the stomach, the length of the intestine is determined by comparing it with the distance from the beginning of the oesphagus to the anus (shown as o~a) and, in the event the stomach is included, the distance from the beginning of the duodenum to the anus (shown as d~a).

II. Abbreviations used for the Explanation of Figures.

Abbreviation	English name	Nomina anatomica
a	Anus	Anus
a. b	Air-bladder	Nectocystis
b	Barbel	Cirrus
b. a	Bone of attachment	--
b. d	Bile duct	Ductus choledochus
b. s	Blind sac	Saccus caecalis
b. v	Blood vessel	Vasa sanguinis
c. d	Cystic duct	Ductus cysticus
c. p	Cardiac part	Pars cardiaca
d	Duodenum	Duodenum
de	Dentine	Substantia eburnea
di	Diaphragm	Diaphragma
e	Enamel	Substantia adamantina
g. a	Gill-arch	Arcus branchialis
g. b	Gall-bladder	Vesica fellea
g. c	Gill-cover	Operculum
g. f	Gill-filament	-
g. o	Genital organ	Organa genitalia
g. r	Gill-rakers	Radii branchiostegi
h. d	Hepatic duct	Ductus hepaticus
	Intestine	Intestinum
. i	Impression of intestine	Impressio intestinalis
. l	Islet(s) of Langerhans	—
. p	Impression of pyloric appendages	Impressio appendicularis
. s	Impression of stomach	Impressio gastrica
l	Liver	Hepar
l. l	Left lobe	Lobus sinister
l. li	Lower lip	Labium mandibulae

l. p. c	Lower pharyngeal teeth	Dentes pharyngis inferiores
m	Mouth	Os
mg	Mesogastery	Mesogastrium
m. i	Middle intestine	Mesogaster
m. l	Middle lobe	Lobus medius
mn	Mandible	Mandibula
m. r	Mesenteric root	Radix mesenterii
ms	Mesentery	Mesenterium
mx	Maxillary	Maxilla
n. c	Nasal cavity	Cavum nasi
o	Oesophagus	Oesophagus
p	Pancreas	Pancreas
p. a	Pyloric appendages	Appendices pyloricae
p. c	Peritoneal cavity	Cavum peritonaeale
p. d	Pneumatic duct	Dactus pneumaticus
pe	Peritoneum	Peritonaeum
p g	Processes of gill-raker	—
ph	Pharynx	Pharynx
p. p	Pyloric part	Pars pylorica ventriculi
pr	Premaxillary	Premaxillare
p. t	Pharyngeal teeth	Dentes pharyngici
p. v	Pyloric valve	Valvula pylori
r	Rectum	Intestinum rectum
r. l	Right lobe	Lobus dexter
s	Stomach	Ventriculus
sp	Spleen	Lien
t	Tongue	Lingua
t. j	Teeth in jaw	
t. p	Teeth on palatine	
t. v	Teeth on vomer	
u. li	Upper lip	Labium maxillare
u. p. t	Upper pharyngeal teeth	Dentes pharyngis superiores

Family DOROSOMATIDAE

1. *Clupanodon punctatus* (Temminck et Schlegel) : Konosiro.

A. Digestive System.

Body very much compressed, somewhat elongate, and elliptically ovate; head rather small, conical. Mouth not large (m-c being ca. 2/7 and m-b ca. 3/13 of head length), subterminal, slightly inferior, upper jaw slightly projecting beyond the lower; lips thin ; no teeth. Buccal cavity small ; Plicae palatinae rather developed in longitudinal folds. Tongue very large, triangular, thick but soft, free, no teeth, smooth, melanin chromatophores absent. No pharyngeal teeth. Gill rakers on all gill-arches subsimilar in form ; length reduces gradually from the anterior arch, those on the first gill arch numerous (over 500 in number), very close-set, long (as long as corresponding gill-filaments), tips blunt, no process; melanin chromatophores scattered in gill-arches.

Peritoneal cavity rather large; peritonium thin and black. Oesophagus moderately long and narrow with thick wall, mucous membrane of which forming 8–9 longitudinal folds. Stomach typical U-shape (blind sac degenerated), cardiac part short but rather wide, mucous membrane of which forming papillae; principal part of stomach, viz., Corpus ventriculi curved tubal, as wide as cardiac part, mucous membrane of which forming ca. 8 longitudinal folds. The Ductus pneumaticus which connects to the middle part of the air bladder starts at this place; pyloric part spherical, wall thick (longitudinal muscle layer developed), similar to the gizzard of birds, mucous membrane forming 5–6 longitudinal folds. Intestine long (as long as body length, ca. 1.8 times d~a), begins at the lower end of the pyloric part, runs directly under it toward the caudal, passing the stomach, makes several short turns, as illustrated, resumes its course and arives at the anus which is situated just before the anal fin; walls of which moderately thick. mucous membrane forming oblique transversal folds. Pyloric appendages numerous, clustering, spread from the lower left front side of the digestive tract to the end of the intestine

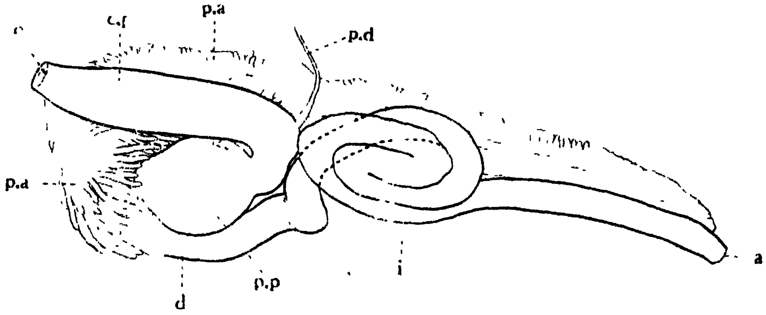
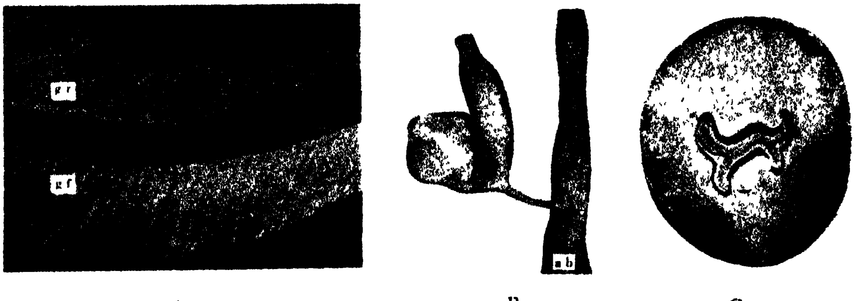


Fig. 10. *Clupanodon punctatus.*



A B C

Fig. 11. *Clupanodon punctatus.* A. Gill. B. Stomach and air-bladder. C. Cross section of pyloric part.

on the right. Hyrtl who made a study of the pyloric appendages of *Clupanodon aureus* stated that the number was so great that it was impossible to count them (1855).

Liver generally consists of 2 lobes, the left lobe being larger than the right, a part of which becomes the hepatopancreas, filling in the gaps made by the pyloric appendages and the intestine; gall-bladder not large situated in front of the pyloric appendages, spherical; Ductus choledochus moderately long. Spleen near the end of the intestine, triangular and small. (Many

Table 1

Stomach contents of *Clupanodon punctatus*

	Date		Aug. 1, 1931	May 15, 1931	June 27, 1935	June 12, 1937	Frequency
	Locality		Miho, Sizuoka Pref.	Collected from Tokyo Fish Market	Sizuura, Sizuoka Pref.	Collected from Tokyo Fish Market	
Stomach contents	Number of fish		10	498	10	5	
Diatom	*Achnanthes*		1	17		1	19
	Actinoptychus			33	1	1	35
	Coscinodiscus	sp₁	2	174	5	2	183
	Cos.	sp₂		15		1	16
	Euodia			49			49
	Fragilaria	sp₁	4	51	1	1	57
	Frag.	sp₂	6				6
	Grammatophora			16		1	17
	Navicula	sp₁	1	123	4		128
	Nav.	sp₂	1	98			99
	Rhizosolenia			10	1		11
	Surirella				3		3
	Thalassiothrix					2	2
	Other species		5	85	4	2	96
Dinoflagellata	*Dinophysis*			5		1	6
	Peridinium		1	67	2		70
	Other species		3	38	3	1	45
Copepoda			2	176	7	4	189
Isopoda			5	22	1		28
Cladocera				36			36

fishes have their spleen near the end of stomach).

B. Feeding Habits.

As far as I know, I believe that the report of Miyafuzi (1928) was the only one ever written concerning the stomach contents of this fish. In 1928, he examined the stomach contents of 334 fishes which were collected from the adjacent waters of Fuzan, Tyôsen. According to his researches, this fish took mainly for its food diatoms and copepods, sometimes larval fishes of sardines and certain species of Crustacea.

Unfortunately, I did not have a chance to make a collection of this fish from various localities, as in the case of sardines, but by the courtesy of a Mr. K. Kurata, the proprietor of "Susi-Ei", a noted "Susi" shop on the Ginza, I was able to obtain nearly 500 stomachs of this fish. From the examination of 523 stomachs I obtained the following results:--

As may be seen from Table 1, this fish seems to be of the voracious kind and takes diatoms and copepods for its pricipal food. Judging from the fact however that it feeds mainly on *Fragilaria, Navicula* and Isopoda, it might be that it goes in pursuit of food to the bottom, but the fact that no sand particles, mud or clam-worms (*Nereis*) could be found in its stomach would indicate that it does not take chiefly the food in the bottom of the sea.

Family DUSSUMIERIIDAE

2. *Etrumeus micropus* (Temminck et Schlegel): Urumeiwasi.

A. Digestive System.

Body elongate, subcylindrical, slightly compressed; head elongate, compressed anteriorly, flattened above, snout long and pointed. Mouth moderate in size (m-c being ca. 1/3 and m-b ca. 5/23 of head length), terminal; lower jaw a little longer than the upper; lips thin. A row of minute teeth in each jaw; fine villiform bands on vomer and palatines. Buccal cavity not large. Tongue large trianguloid, upper surface of which rough because of the existence of villiform teeth, free, Musculus hypobranchiales developed; melanin chromatophores absent. Pharyngeal teeth rudimentary. Gill-rakers coarse, 49 in average number, long (the length being ca. 2/3 of corresponding gill-filaments), flattened somewhat, slender, and pointed; process numerous.

Peritoneal cavity comparatively large; melanin chromatophores scattering in the peritoneum. Oesophagus short, with thick wall, mucous membrane of which forming 12 longitudinal folds. Stomach Y-shape; blind sac longer than the cardiac part, cardiac part being longer than the pyloric part. Pyloric part ovate, wall of which the thickest. Mucous membranes of the cardiac part and the blind sac form 12 longitudinal folds, the same as in the oesophagus. Intestine moderately wide, short (as long as d⁓a), wall thin; there is no valve between the intestine and the rectum, the mucous membrane both of which forming transversal folds. Anus opens just in front of the anal fin. Pyloric appendages consist of a mass of small clusters, numbering about 1000, located primarily at the lower left of the stomach. In Vol. 20 of their book, Cuvier and Valenciennes (1828–1849) describe the pyloric appendages of *Dussumieria acuta* as " numerous ".

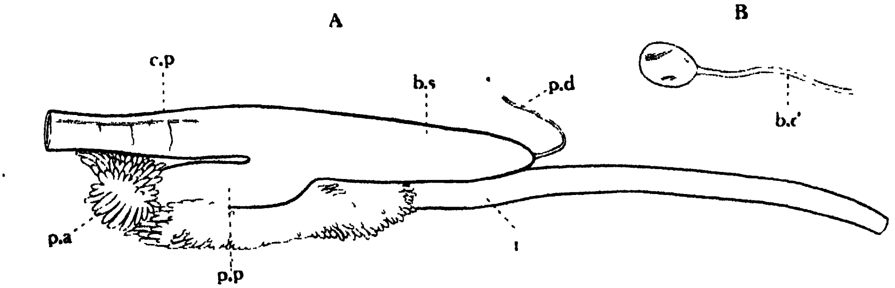


Fig. 12. *Etrumeus micropus.* A. Digestive tract. B. Gall-bladder.

Liver polylobes, thin, overhanging the upper right of the stomach. Gall-bladder almost spherical, located at the upper part of the pyloric part. Spleen small, semi-circular, situated near the middle part of the stomach. Air-bladder long, fusiform; Ductus pneumaticus short, communicating with the end of the blind sac.

B. Feeding Habits.

Table 2

Stomach contents of *Etrumeus micropus*

Date	Mar. 21, 1930	Des. 14, 1932	May 10, 1933	Nov. 5, 1933	May 7, 1939	Frequency
Locality	Miyatu, Kyôto Pref.	Misaki, Kanagawa Pref.	Kawatumae. Tiba Pref.	Okinose, Sizuoka Pref.	Tokyo Fish Market	
Number of fish / Stomach contents	10	3	11	12	5	
Certain larval fishes	2	3	5	10		20
Larval fishes of Clupeidae			1		4	5
Larvae of Gastropoda					1	1
Sagitta	2					2
Certain Copepoda	9		1			13
Oithona sp.			3			3
Zoea larvae			2			2
Amphipoda			2			2
Schizopoda		1	1		3	5

I collected samples of this fish in 5 different regions around Japanese waters in various seasons, and the results of my examination revealed that this fish was inclined to be more carnivorous in its feeding habits than the other sardine-like fishes.

3. *Spratelloides japonicus* (Houttuyn): Kibinago.

A. Digestive System.

Body elongate, subcylindrical; snout rather long and pointed. Mouth rather small (m-c being ca. 3/8, m-b being ca. 1/3 of head length). Upper jaw a little shorter than the lower; maxillary comparatively broad. Teeth none. Buccal cavity long and narrow; tongue small, semi-elliptic, the upper surface of which somewhat concave, translucent, teeth and melanin chromatophores both absent, free. No pharyngeal teeth. Gill-rakers long and slender, tips pointed, length of which being ca. 3/2 of corresponding gill-filaments, close-set, ca. 50 in number.

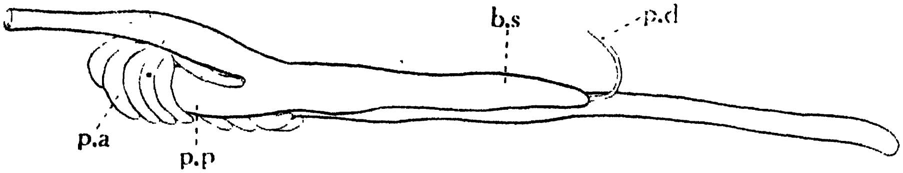


Fig. 13. *Spratelloides japonicus.*

Peritoneal cavity long, peritonium thin, and rich in melanin chromatophores. Oesophagus moderately long and narrow, where the mucous membrane consists of 8 to 9 of longitudinal folds. Stomach assumes Y-shape, blind sac very long, Ductus pneumaticus starts from its end, cardiac part a little longer than pyloric part, mucous membrane of stomach consists of about 7 longitudinal folds, wall of pyloric part moderately thick. Intestine short and narrow, running almost straight towards the anus, length of which being ca. 3/5 of body length, and as long as d~a, wall thick, folds of the mucous membrane zigzag (or W-shape). Anus directly in front of the anal fin. Pyloric appendages long and broad, a majority of them situate at the right side of the stomach, tips pointed, bent a little, 15 in number.

Liver small, spherical, situates at the left side of the digestive tract, right lobe is so small that liver is apt to be mistaken as single-lobed; gall-bladder very small spherical. Spleen moderately long and large.

B., Feeding Habits.

Table 3

Stomach contents of *Spratelloides japonicus*

Date	Locality	Number of fish	Body length (cm)	Stomach contents
Nov. 7, 1934	Sigedera, Sizuoka Pref.	11	4.7~6.1	Indistinct
Feb. 14, 1935	Nakatu, Ôita Pref.	10	Av. 6.3	do.

As shown in Table 3, I made a collection of 21 fishes from 2 localities in 2 different times, however, I could not find anything but mucous in their stomachs. In addition, the folds of the mucous membrane of their digestive tracts were all distinct, and there were no traces that they had eaten fully.

Family CLUPEIDAE

4. *Clupea pallasii* (Cuvier et Valenciennes): Nisin.

A. Digestive system.

Body elongate, compressed, especially in front of the eyes. Mouth terminal, not large (m-c being ca. 1/2 and m-b ca. 1/4 of head length), oblique upward, lower jaw longer than the upper. Small and weak teeth on the intermaxillary and mandible, none on the premaxillary, vomer with 2 rows of small teeth. Buccal cavity moderately large; Plicae palatinae forming longitudinal folds. Tongue moderately large, trianguloid, free, armed with a small patch of minute teeth, melanin chromatyphores absent (Pl. III, Fig. 4); Musculi hypobranchiales developed. Pharyngeal teeth exist only rudimentary. Gill-rakers long (a little longer than corresponding gill-filaments), slender, tips blunt, thickly grown, the number of which ca. 55–72; process numerous but not so many as *Sardinia melanosticta* (Pl. IV, Fig. 11).

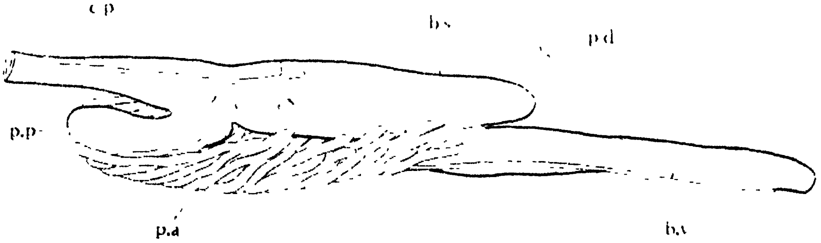


Fig. 14. *Clupea pallasii.*

Peritoneal cavity rather large, fusiform; peritonium thin, dusky. Oesophagus short but rather wide, with thick wall, mucous membrane of which assuming ca. 20 distinct longitudinal folds. Stomach Y-shape: blind sac longer than the pyloric part and the pyloric part a little longer than the cardiac part. Mucous membrane of the cardiac part constituted by double nets among the 7 to 8 wider folds of the 20 longitudinal folds of the oesophagus (Pl. VII, Fig. 15); blind sac large, fusiform, wall of which thinner than that of the cardiac part, especially the end; folds of the mucous membrane subsimilar to those of the cardiac part; Ductus pneumaticus starts at its end; pyloric part ovate, walls thick, pylorus having a strong valve, viz. pyloric valve; mucous membrane consists of single net and longitudinal folds. Intestine almost a straight line to the anus, length of which being ca. 1/2 of body length, as long as d~a, moderately narrow, walls rather thin, mucous membrane of the beginning of the intestine forming polygonal nets but soon changing to transversal folds, namely, ring folds and not spiral folds (Pl. IX, Fig. 8). There are nets which are not distinct among these folds. Pyloric appendages rather long, the length differing somewhat, 25 to 27 in number, located at the lower end of the pyloric part and spread to the right side of the stomach.

Liver consists of 2 lobes which are not very distinct, located at the left side of the digestive tract, and covers almost 1/3 of the cardiac and pyloric parts, pyloric appendages and the blind sac. Gall-bladder spherical and small; Ductus choledochus short. Pancreas white, located between the pyloric appendages and along the digestive tract.

The digestive tract of the European herring was studied by Cuvier (1810), Rathke (1824), Meckel (1833), Hyrtl (1855) and Jacobshagen (1911); especially Jacobshagen made a careful and detailed study of the folds of mucous membrane of the intestine.

B. Feeding Habits.

As it is important to know what kinds of food are taken by the herring, which is one of the most important fishes from the fishery point of view, a great number of reports have been written in countries all over the world. Owing to various circumstances, I could not collect sufficient samples of this fish as in the case of sardines about which I shall write in the next chapter. So instead of discussing the feeding habits of this fish from my personal meagre results, I have decided to take for my basic arguments the contents of these various reports.

Regarding the food of the herring collected around Japanese waters, Kuragami (1930) who obtained his material from adjacent waters of Hokkaidô, stated that its food Consisted of minute Crustacea, especially copepods. He also pointed out that it took food during the spawning season, and that it went ever so energetically in pursuit of food after it had delivered its spawn. The Hokkaidô Fisheries Experimental Station (1930) ascertained that the herring which migrated to the neighbouring waters of Syakotan had come in pursuit of food and not for spawning. Takayasu and two others (1930) reported that the herring which had entered into Lake Tôfutu fed on *Mysis*.

As for the feeding habits of the herring in foreign waters, Widegren (1873) wrote in his report on its food: "The food of the young, as well as the grown herring, consists chiefly of small crustaceous animals ······. The herring, after spawning, usually migrates to the deep-sea to seek food, and does not return till it has again gained in flesh and strength." Ljungman (1879) said of the Swedish herring that it took copepods for its principal food and pursued food during the spawning season too; and that it migrated definitely for food. It is to be noted that in his report of 1875, he stated that the herring on the Coast of Bousalän ate small insects such as *Ganeskar*. Hensen (1879) studied the food of American herring and found that its principal food was Crustacea, and that the color of the digestive tract was sometimes red, yellow or black, according to the nature of food it took. Day (1882) studied the English herring and agreed, although not entirely, with Hensen, and he reported that it ate quite a bit of fishes besides the Crustacea. American scientists Weber and Wilson (1920) examined many herring stomachs from a cannery point of view and made a valuable report on the connection of these various stomach contents had with bacteria. The results of their analyses showed that they consisted of copepods and schizopods. Hardy (1924) found from his study of the herring on the east coast of England, that there were periods, in autumn and winter, during which it took no food at all.

The name of Jespersen (1928) cannot be forgotten in connection with the study of the feeding habits of the herring. From November 1922 to April 1926, he made a collection of 7,316 herrings from Danish waters (of which 2,827 were larval herrings) and examined their stomach contents, from which he found that 93% consisted of Crustacea and the rest of fish ova, fishes and polychaetes, and that contrary to Hardy's view, they took food all the year round. He made a detailed study of the seasonal change which took place in their food, the connection between stomach contents and the plankton of various fishing grounds, etc., about which I shall not enter into details here on account of the space it will require. In 1932 he compared the stomach contents of the herring caught in Icelandic waters by purse-nets and gill-nets, and pointed out that the herrings caught by purse-nets had a large quantity of plankton (chiefly copepods) in their stomachs, while those caught by gill-nets contained materially less, and some had empty stomachs, which were to indicate, he argued, that their food had a close connection with their environment. Savage (1931) examined the stomach contents of a great many herrings off the coast of England and compared them with the plankton collected in various fishing grounds, and found that the species which were abundant in the fishing grounds were also plentiful in the stomachs of the herrings. As the result of a recent study made by Wailes (1935) of the food of young and adult herrings in southern British Columbia waters, it was found that the herring began to take food when it grew over 9 mm, and that the chief food of the adult herring was Copepoda in the spring and Euphausia in other seasons.

There are many other reports on the feeding habits of the herring besides those I have mentioned above, but as they are more or less the same, I shall omit them.

Finally, I have come to the conclusion that its principal food consists of the Crustacea, especially copepods and schizopods, and a small quantity of larval fishes and polychaets, and that it takes food all the year round. I think that this fish makes an interesting contrast with the sardine whose principal food is the diatom.

5. *Sardinia melanostica* (Temminck et Schlegel) : Maiwasi.

A. Digestive System.

Body elongate, subcylindrical, moderately compressed, snout triangular. Mouth slightly oblique, not large (m-c being ca. 5/11 and m-b ca. 4/17 of head length), not protrusile; lower jaw considerably longer than the upper; each jaw armed with a row of rudimental teeth. No teeth on vomer and palatines. Buccal cavity large; Plicae palatinae forming approximately 10 longitudinal folds. Tongue moderately large, rectangular, free, smooth and no teeth, rich in melanin chromatophores; Musculi hypobranchiales developed. Pharyngeal teeth absent. Gill-rakers long (the length of which being ca. 3/5 of corresponding gill-filaments), flat, tips pointed, thickly grown, the number of which vary somewhat but generally about 150; process numerous. Regarding the gill-rakers of sardines, Kishinouye (1907) was the first in Japan who described on them. Recently, Thompson (1926) found that the shorter gill-rakers of the adult fish of *Sardinia sajax* grew at the inner flexure of the first gill-arch, and Sakô (1938) found similar facts with *S. melanosticta*. When Scofield (1934) was making a research of the development of the gill-rakers of *S. caerulea*, he made a detailed explanation of how the number and form of the processes of gill-rakers changed with age. Nakai (1938) took *S. melanosticta* for his material, and as the result of a careful study, he found that as this fish grew from 1.70 cm to 19.5 cm, the number of gill-rakers increased from 11 to 163, and length increased from 0.07 mm to 14 mm, and that the number of process of the gill-raker increased from ca. 30 to ca. 120, and the length increased from ca. 0.02 mm to 0.18 mm. Pharynx short and funnel-shaped.

Peritoneal cavity moderate in size, fusiform; peritonium thin, rich in melanin chromatophores Oesophagus moderately long, wall thick; mucous membrane consists of a group of papillae. Stomach Y-shape, cardiac part being as long as blind sac, and pyloric part comparatively shorter. Cardiac part, tube-like, with thick wall, mucous membrane of which forming oblique bands (Pl. VI, Fig. 1); blind sac fusiform, wall of which moderately thick, mucous membrane forming longitudinal serpentine folds (Pl. VI, Fig. 2). There is a long, narrow tube called the Ductus pneumaticus at the end of the blind sac which communicates to the air bladder; pyloric part somewhat

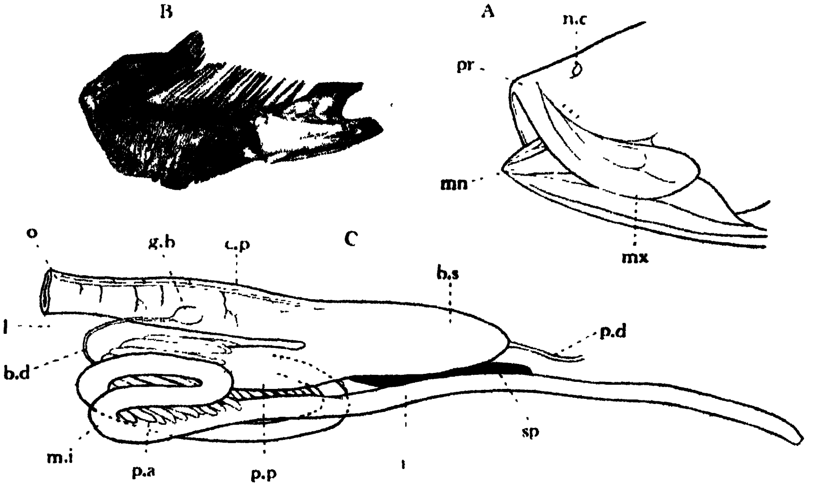


Fig. 15. *Sardinia melanosticta*. A. Head. B. Gill. C. Digestive tract.

ovate, wall of which very thick, longitudinal muscle layer developed, mucous membrane forming longitudinal folds made by rows of small papillae (Pl. VI, Fig. 3), epithelium chitinous. Intestine rather narrow, moderately long, length of which being a little longer than the body length, ca. twice d~a. No difference between the duodenum and the rectum, wall thin, mucous membrane forming closely connected transversal folds. Anus just in front of the anal fin. Right at the beginning of the intestine there is a bunch of pyloric appendages. They are generally situated at the right side of the pyloric part of the stomach and do not vary much in length. None of them are long, but there is quite a variation in their number. They average about 120.

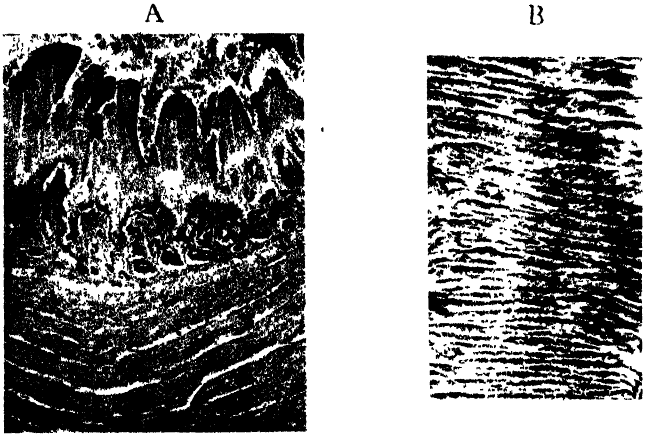


Fig. 16. *Sardinia melanosticta.* A. Cross section of pyloric part of stomach. B. Folds of intestinal mucous membrane.

Liver, thin, consists of 2 lobes (ambiguous as polylobes), the left lobe being large; Impressio appendicularis rather distinct. Gall-bladder spherical and small; Ductus choledochus long but not so long as the length of liver. Colour of the pancreas white and apt to be taken for fat, and which located between the pyloric appendages, at the end of stomach and along the intestine. Situated midway between the blind sac and the intestine is the spleen, large, but thin. Air-bladder large, long and spindle shape, from the middle part of which starts the Ductus pneumaticus and joins to the end of the blind sac of stomach.

·Kishinouye (1907) was the only one to observe the stomach and intestine of this fish. None of the scholars, such as Cuvier, Home, Rathke and Jacobshagen studied them. He found that the stomach of this fish had a big blind sac, that its intestine was long and that the pyloric appendages numbered about 120. Day (1882) made a study of the digestive system of *Clupea pilchardus*, a species closely allied to this fish. He reported that the oesophagus of this fish had several rows of large proventricular glands, and that the wall of the pyloric part of stomach was very thick.

B. Feeding Habits.

Due no doubt to the fact that sardines, namely the fish belonging to the Genus *Sardinia*, are important from the standpoint of fishery and their being, so to speak, rather a cosmopolitan fish, reports on the feeding habits of this fish run into numbers.

Beginning with the report of Kishinouye (1907) on Japanese *Sardinia melanosticta*, there are studies of the Nagasakiken Fisheries Experimental Station (1930), Yankovskaya (1937) and Nakai (1938). Studies on foreign species, *Sardinia caerulea*, were made by Thompson (1926, 1927), Lewis (1929), Parr (1930), and Scofield (1934), on *Sardinia pilchardus* by Chester (1835), Couch (1835, 1867), Yarell (1836), Hamilton (1843), Sauvage (1865, 1886, 1889, 1890), Bertram (1869), Lilljeborg (1881), Day (1882), Houghton (1883), Wilcocks(1883), Albert (1887), Guerne (1887), Monticelli (1887), Poucket and Guerné (1887), Vaillant and Henneguy (1887, 1888), Marion (1888, 1889, 1894), Gobin (1891), Henneguy (1891), Roché (1893), Smitt (1893), Fabre-Domergue (1896), Benard (1903), Künstler (1903), Richard (1904), Ropers (1906), Rodriguez (1907), Cépède (1907, 1908, 1910), Steuer (1908), Ravertet-Wattel (1909), Summer, Raymond and Cole (1913), Swithinbank and Bullen (1913, 1914), Roule (1914), Lebour (1918, 1919, 1921, 1927), Buen (1919, 1927, 1928), Blin (1923), Navarro (1926), Jacquemé (1926), Belloc (1930), Hart and Wailes (1931). On *Sardinia neopilchardus*, Roughly (1916) made a report on this fish and Arthur (1883) did likewise on *Sardinia sajax*,

It will be seen from these reports that they all agree in that sardines make the zoo-plankton and the phyto-plankton their staple food, but when it comes to the question of whether this fish selects its food or not, opinion varies considerably. For instance, Kishinouye (1907) says " It does not ", while the Nagasakiken Fisheries Experimental Station (1930) says it makes special pursuits. Lewis (1929) maintained that *S. caerulea* went in pursuit of diatoms and dinoflagellates, the same as in the case of the zoo-plankton, but Parr (1930) argued that diatoms and dinoflagellates were ingested incidentally when it was in pursuit of the zoo-plankton.

Table 4

No.	Station	Date	Locality	Number of fish	♂ : ♀	Average Body weight (g)	Average Body length (cm)	Average Body height (cm)	Average Body breadth (cm)	Average Weight of stomach contents (g)
1	A	Oct. 16, 1930	Hunkawan, Hokkaidô	20	6:14	—	13.7	—	—	—
2	B	Jan. 28, 1938	Onahama, Hukusima Pref.	10	—	35.1	14.6	—	—	—
3	C	July 20, 1929	Komatuhama, Tiba Pref.	50	40:10	22.3	12.0	2.3	1.6	0.59
4		Dec. 25, 1929	do.	30	9:21	21.7	12.0	2.2	1.2	0.71
5		Mar. 3, 1930	do.	25	12:13	16.7	11.2	2.0	1.2	0.31
6		July 28, 1930	do.	25	7:18	30.0	13.0	2.6	1.6	0.59
7		Nov. 15, 1930	do.	25	15:10	23.0	12.5	2.3	1.4	0.76
8	D	Aug. 13, 1930	Katagai, Tiba Pref.	30	12:18	33.9	13.6	2.6	1.7	0.74
9	E	Mar. 7, 1930	Yenoura, Sizuoka Pref.	25	19: 6	33.5	14.2	2.7	1.8	0.70
10		June 27, 1930	do.	25	5:20	13.0	10.2	1.8	1.2	0.36
11	F	Mar. 4, 1980	Miyatu, Kyôto Urb. Pref.	25	18: 7	39.9	15.1	2.6	1.8	1.02
12	G	July 10, 1936	Ôita, Ôita Pref.	10	—	31.0	14.2	—	—	—

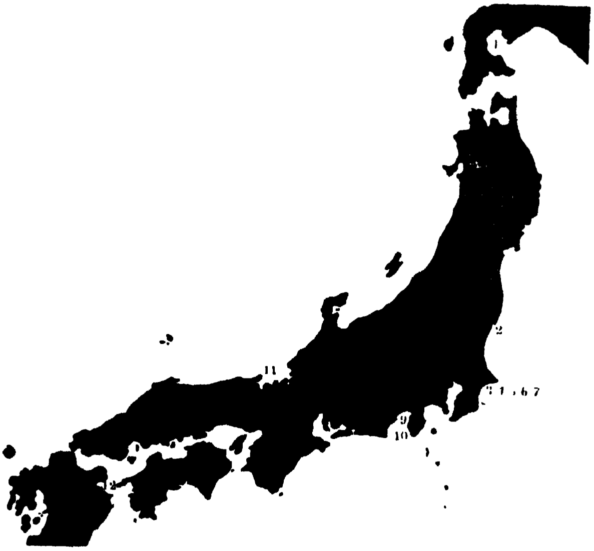


Fig. 17. Map showing the place of collection of sample.

I made a collection of 300 fishes in 12 times from 7 different localities in the waters around Japan and studied minutely their stomach contents to the best of my ability. In identifying the species of diatoms and dinoflagellates, as previously stated, I put them in weak hydrochloric acid and carmine in order to obtain better and clearer observation.

As the result of this examination is very voluminous and bulky, I have to shorten it to the extreme. In the first place, I divided the stomach contents into 5 groups, namely, Diatom, Dinoflagellata, Copepoda, other Crustacea and the rest. Then, I tried to determine to which group the dominant species might be assigned and which were the staple species of each group.

It may be seen from the next table that *Sardinia melanosticta* takes, as phytoplankton, diatoms like *Coscinodiscus*, *Pleurosigma* and *Bidulphia*; as zooplankton, first Copepoda; this point is worth comparing with other fishes that take plankton for food. Ostracoda, Cladocera and *Tinntinopsis* come next and rarely Amphipoda and Schizopoda. Sand particles and sponge spicules were incidentally forced in when the drag-net was hauled up to the sandy shore.

After several experiments, I found that, in the majority of cases, the dominant species of the plankton found in the stomach contents of the sardines and those found in the fishing grounds were identically the same. Those results are almost similar with those of Yankovskaya (1937) and Nakai (1938).

It is, however, worthy of note that I have been told by experienced fishermen that sardines, which acquire an enormous appetite after they have spawned, go schooling in pursuit of copepods and schizopods. Lastly, I have to tell my readers that the colour of the stomach contents of this fish and

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Table 5

Stomach contents of *Sardinia melanosticta*

No.	Dominant group	Stomach contents				
		Staple species				
		Diatom	Dinoflagellata	Copepoda	Other Crustacea	Rest
1	Copepoda	*Coscinodiscus marginatus*, *Cos. asteromphalus*, *Pleurosigma* sp.	*Ceratium massilense*	*Paracalanus parvus*		*Tintinnopsis* sp., *Polychaeta* larvae
2	Diatom	—	—	—	—	—
3	Diatom & Dinoflagellata	*Skeletonema costatum*, *Coscinodiscus radiatus*, *Pleurosigma affine*	*Dinophysis ovum*, *Phalacroma mitra*, *Pyrophacus horolongicum*	*Setella* sp., *Oithona nana*	*Cladocera*	Sand particle, Pollen of Conifereae
4	Diatom	*Actinoptychus undulatus*, *Biddulphia longicrusis*, *Actinoptychus* sp.	*Peridinium Steinii*, *Dinophysis homunculus*	*Microsetella* sp., *Euchaeta* sp.	Ostracoda	Sponge spicule (Monaxon type), Sand particle
5	Diatom & Dinoflagellata	*Coscinodiscus sp.*, *Navicula* sp., *Eucampia zoodiacus*	*Peridinium* sp., *Podoplamas* sp.	*Calanus* sp.	*Zoëa* larvae, *Evadne* sp.	Sand particle
6	Diatom	*Coscinodiscus* sp., *Fragilaria* sp. *Biddulphia aurita*	*Pyrophacus* sp.	Ceratin Copepoda	Rotatorium, Certain insect	Sponge spicule (Monaxon type), *Halosphaera viridis*
7	Diatom	*Coscinodiscus radiatus* *Melosira* sp. *Eucampia* sp.	*Dinophysis hastata*, *Peridinium* sp.	Certain Copepoda	Cladocera	
8	Diatom	*Bacteriastrum delicatulum*, *Coscinodiscus* sp., *Rhizosolenia stolterfothii*	*Pyrophacus horolongicum*, *Peridinium divergens*	*Oithona* sp., *Microsetella* sp.	Amphipoda	Sponge spicule, *Tintinnopsis*
9	Diatom	*Coscinodiscus radiatus*, *Cos. lineatus*, *Cos. excentricus*, *Navicula* sp.	*Peridinium roseum*, *Peridinium depressum*	*Oithona nana*, *Paracalanus* sp.	*Evadne Nordomanni*	Sponge spicule
10	Copepoda & other Crustacea	*Pleurosigma* sp. *Thalassiothrix Frauenfeldii* *Fragilaria* sp.	*Gonyaulax* sp., *Ceratium tripos*	*Microsetella*, *Corycaeus obtusus*, *Oncea* sp.	Nauplius larvae of Cirripedia, Ostracoda, Rotatorium	Sponge spicule (Monaxon, Tri, Tetra, Poly-axon), *Tintinnopsis*
11	Copepoda & other Crustacea	*Chaetoceras diadema*, *Skeletonema costatum*	*Ceratium tripos*	*Oithona* sp., *Calanus finmarchicus*, Egg of Copepoda	*Euphausia pellucida*, *Megalopa* larvae of crab, Ostracoda	*Cyttarocyliz denticulata* *Oikopleura*
12	Copepoda	*Coscinodiscus excentricus*, *Cos.* sp., *Chaetoceras* sp.	*Peridinum* sp. *Ceratium tripos*	Certain Copepoda	Ostracoda (?), Amphipoda	*Tintinnopsis* sp.

its intestine, externally, is dependent upon the food it takes whether it takes the phytoplankton or the zooplankton. If it is the former, the colour is green and in the case of the latter brown. Hart and Wailes (1931) write that in America the former is commonly known as the "green food" and the latter as the "red food".

6. *Harengula zunasi* (Bleeker): Sappa.

A. Digestive System.

Body elongate, much compressed; head rather small, compressed, flattened above. Mouth almost vertical, the lower jaw slightly projecting; teeth in lower jaw very minute, grow in a single row, those in the upper rudimentary. Mouth cavity compressed sidewise; villi-form teeth present on the posterior part of palatines and on the middle part of tongue; tongue trianguloid, rather small, thin, free. No pharyngeal teeth. Gill-rakers long (a little longer than corresponding gill-filaments), slender, tips pointed, fine, 80 85 in number, processes short but numerous.

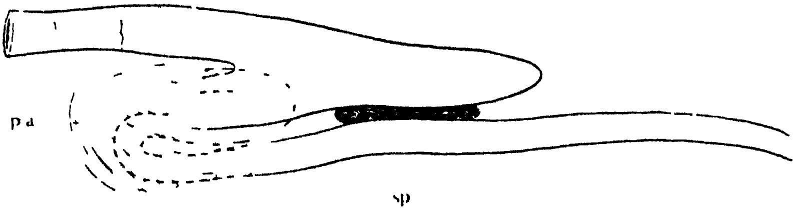


Fig 18 *Harengula zunasi*

Peritoneal cavity compressed sidewise; peritoneum thin and black. Oesophagus short, narrow, wall thick. Stomach Y-shape, wall moderate (also the pyloric part); cardiac part, blind sac and pyloric part almost same in length. Mucous membrane of oesophagus consists of almost 18 longitudinal folds, while that of cardiac part of stomach has about 11 longitudinal folds of the papillary processes; the mucous membranes of blind sac and pyloric part consist of common longitudinal folds. Duodenum narrow, curves in S-form at the right side of pyloric part of stomach. Intestine runs straight from the end of duodennm to anus. Whole length of intestine being ca. 1/3 of d∼a; the wall of intestine thin, the mucous membrane forms closely connected transversal folds. Pyloric appendages short, tips bluntly pointed, 36 39 in number, locate at the left side of stomach.

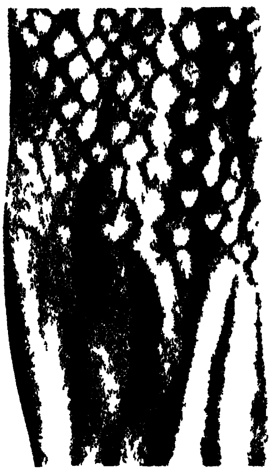


Fig 19 *Harengula zunasi* Folds of mucous membrane of cardiac part of stomach

Liver rather large but thin, consists of a large left lobe and, a small right lobe, gall-bladder spherical; bile duct and cystic duct short. Pancreas distributes mainly between the pyloric appendages. Spleen rather large. Air-bladder large, spindle shape; Ductus pneumaticus communicates to the end of the blind sac of stomach.

B. Feeding Habits.

From my examination of the stomach contents of 30 fishes, about 8 cm in length, caught from the River Sumida, near the Imperial Fisheries Experimental Station, on Aug. 27, 1936, I found that they consisted of mainly the diatoms such as *Navicula* or *Coscinodiscus*, and the copepods such as *Acartia*.

Family ENGRAULIDAE

7. *Engraulis japonicus* (Temminck et Schlegel): Katakutiiwasi.

A. Digestive System.

Body elongate, subcylindrical. Mouth large (m-c being ca. 2/3 and m-b ca. 1/4 of head length); snout projecting considerably beyond the mandible; mouth cavity not so large due to the width of the mouth cleft, but when the mouth is once fully opened, the mouth cavity becomes materially enlarged. Jaws armed with a row of minute teeth; none on the vomer, palatines and pharyngeal bones. Tongue trianguloid, small, free, thin and smooth; no chromatophores, Musculi hypobranchiales developed. Gill-rakers long (the

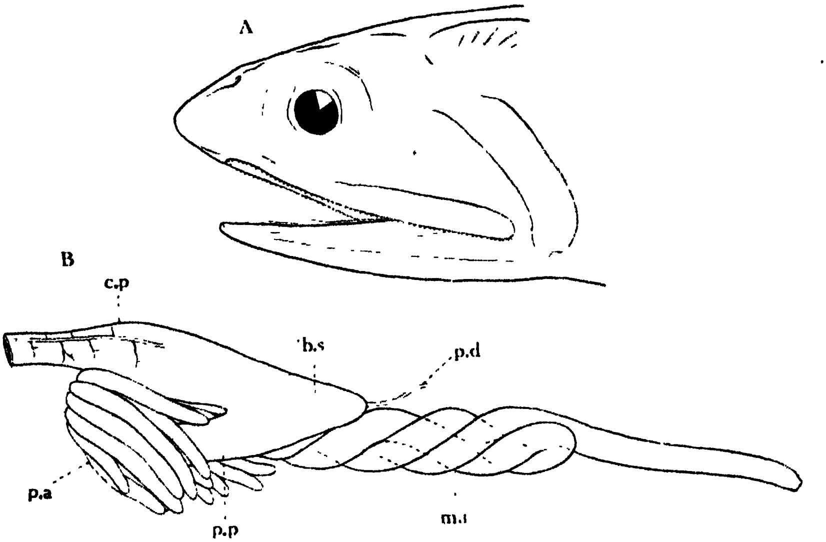


Fig. 20. *Engraulis japonicus*. A. Head. B. Digestive tract.

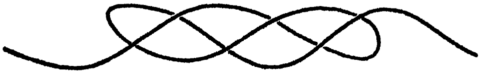


Fig. 21. *Engraulis japonicus*. Diagram showing the winding-type of intestine.

length being ca. 3/2 of corresponding gill-filaments), slender, rather flat, tips pointed, closely set, about 60, processes well developed.

Peritoneal cavity fairly long, subcylindrical; peritoneum thin and black. Oesophagus long in comparison with that of the sardine, wall thick; about 25 wavy, longitudinal folds constitute the mucous membrane. Stomach Y-shape, greyish white. Pyloric part ovate, wall thick. Approximately 10 wide longitudinal folds constitute the mucous membrane of the cardiac part, net-work folds constitute the blind sac, and 5 to 6 deep longitudinal folds constitute the pyloric part. Intestine long (the length being 3/4 to 5/4 of body length, or av. 3.5 times d~a, but varying considerably according to individuals), black, presenting one of the most characteristic types of winding, i. e., as the Fig. 20, B shows, it would seem that it simply coils itself round, but on closer examination, it will be seen that this winding consists of the combination of two different modes, namely, the intestine firstly bends in N-shape and secondly the each bending part coils in opposite directions around the opposite axis as shown in Fig. 21; wall rather thick, narrow; folds of the mucous membrane transversal, closely set together; anus opening just in front of the anal fin. Pyloric appendages large and broad, tips pointed, 25 in average number.

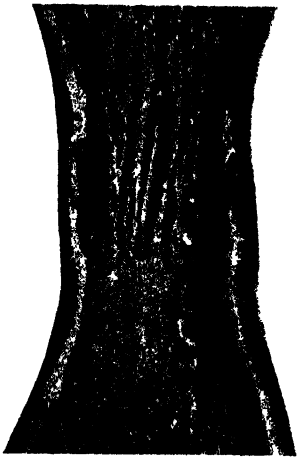


Fig. 22. *Engraulis japonicus.* Folds of mucous membrane of stomach.

Liver moderately large, consists of 2 lobes or more, thin, embracing a part of the stomach and the pyloric appendages from below. Gall-bladder elliptic, small; Ductus choledochus short. Spleen ovate, located to the right of the blind sac and back of the pyloric appendages. Air-bladder large, wall thin; Ductus pneumaticus communicates with the blind sac of the stomach.

B. Feeding Habits.

As already stated, *Sardinia melanosticta* which collected from Miyatu, Kyôto Urban Pref. in Mar. 10, 1930 had taken a good quantity of animal food in addition to diatoms, however, 30 *Engraulis japonicus*, about 6 cm in body length, which collected at the same time took merely the diatoms. From this I came to the conclusion that the food of this adult fish consists chiefly of the diatom, although it would seem, judging from the size of its mouth, that it can take larger animals. According to Nishikawa (1901) who made a thorough study of the life history of this fish, the young fed chiefly on copepods, but when it reached the adult stage, it specialized in the diatom and, at times, ate the young of its own.

8. *Coilia mystus* (Linné): Etu.

A. Digestive System.

Body greatly elongated and much compressed. Head small and compressed. Mouth large (m-c being ca. 1/2 and m-b ca. 1/3 of head length), oblique, and subinferior. 1 row of small teeth in each jaw, on the vomer and palatines. Buccal cavity not large; folds of the palatal mucous membrane oblique; tongue very small, armed posteriorly with a median patch of teeth. Gill-rakers long (as long as corresponding gill-filaments), close together, slender, tips bluntly pointed, 42–44 in number, process numerous; pharyngeal teeth fine.

Peritoneal cavity compressed sidewise; a few melanin chromatophores on the peritoneum. Oesophagus moderately long and thick, wall thick; the mucous membrane of which consisting of 30 longitudinal folds. Stomach Y-shape; cardiac part as long as the blind sac, the pyloric part being a little shorter; walls of the 3 foregoing parts all about the same thickness; although the end of the blind sac is pointed, according to my humble investigations, there does not seem to be Ductus pneumaticus which connects to the air-bladder as may be found in other sardine-like fishes. Mucous membranes of the cardiac part and the blind sac consist of 7 longitudinal folds, while those of the pyloric part 8. Except for the duodenum curving in the shape of an U, the intestine otherwise constitutes a straight line and runs along the right side of the stomach, the length of which being a little longer than d~a. Wall of the intestine thin, the intestine itself being broad, the mucous membrane having transversal folds. Pyloric appendages broad, tips pointed, 15 in average number, 4 to 5 of which being short and the rest long. Bunches of these are located mainly on the right side of the stomach.

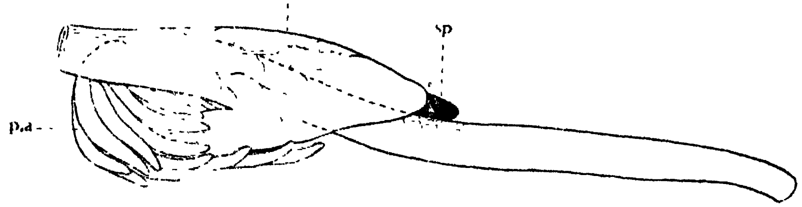


Fig. 23. *Coilia mystus.*

Liver large, composed of left and very small right lobes, thick, overhanging and covering the stomach. The length of the liver is almost the same as that of the stomach. Gall-bladder spherical. Spleen, not large, connected with the end of the blind sac. Pancreas well developed between the pyloric appendages. Air-bladder silvery and spindle-form.

The significant point in the digestive organs of this fish lies in that its intestine does not wind so much as in the case of *Engraulis*, and although the digestive organs of the former are reddish in colour, in the latter they are of black.

B. Feeding Habits.

In the spring of 1935, through the courtesies of Mr. H. Watanabe of the Hukuokaken Fisheries Experimental Station at that time, I obtained 20 of this fish, each being 7.8 cm to 26 cm, caught at the mouth of the Tikugo

River on the 24th of April, 1935. From my examination of the stomach contents of these samples, I found that their chief food consisted of Crustacea, of which *Acetes japonicus* constituted the major portion, and the smaller they were, the more voracious they were apt to be. It appeared to me that the amount of food which they took decreased as they grew larger, that is, with the run up-stream.

Family SALMONIDAE

9. *Oncorhynchus keta* (Walbaum): Sake.

A. Digestive System.

Body elongate, compressed. Mouth moderate in size but the shape and size vary in sexual dimorphism, that is, the upper and lower jaws of the virile male project out much more than those of the female in the same state; in the male the end of the upper jaw turns down like a hook and the jaw teeth change accordingly and grow so long that they finally become sharp hooked teeth, while those of the female remain small. Buccal cavity moderately large; Plicae palatinae consists of fine longitudinal folds; melanin chromatophores present on the palate. Tongue rather large, rectangular, almost triangular at the tip, rather thin, free, melanin chromatophores rather densely distributed, there are longitudinal folds and teeth. Teeth on vomer and palatines, larger those in jaw; none on the 5th branchial arch, only folds of the mucous membrane. Gill-rakers somewhat flat and short, the length of which being ca. 1/4 of corresponding gill-filaments, strong, tips pointed, not closely set on the gill arch, 22 to 24 in number, oblique to the gill-arch; processes rudimentary (Pl. IV, Fig. 9). The number of gill-rakers of this fish became the special study of many a scholar. For instance: Jordan and Evermann (1876) said there were 24; Koshida (1910) 20 to 24; S. Tanaka (1921) 24; Ôno (1928) 22 to 24; Kawakami (1934) 22 to 24; and that the gill-rakers of the male numbered a little more than those of the female.

Peritoneal cavity rather large, a few melanin chromatophores scattering in

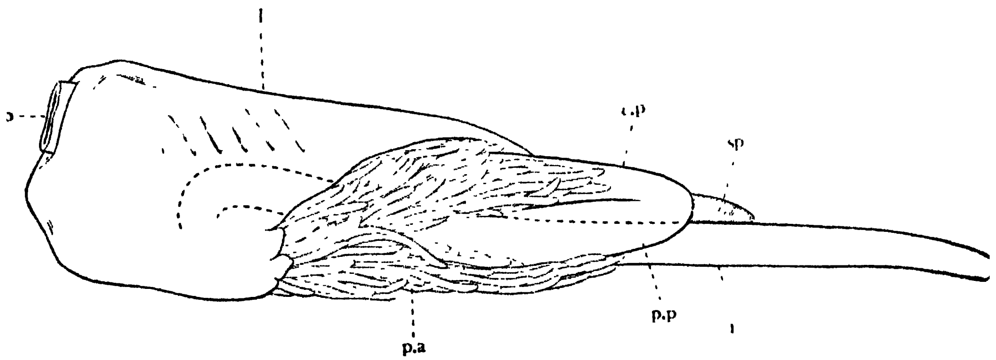


Fig. 24. *Oncorhynchus keta.*

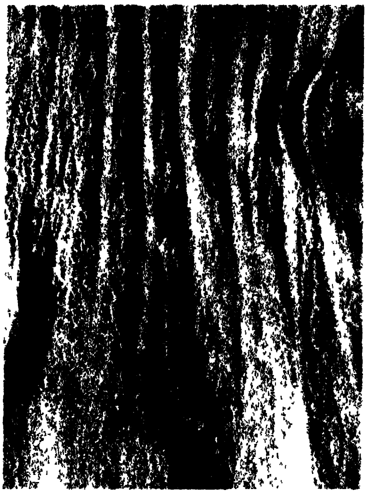


Fig. 25. *Oncorhynchus keta*. Folds of mucous membrane of stomach.

the peritoneum. Oesophagus short and wide, mucous membrane consisting of 10 longitudinal folds. Stomach perfect V-shape; the cardiac and pyloric parts both being the same length, and long; blind sac, a rudimentary existence. Wall of the stomach thick, folds of the mucous membrane, as illustrated, being longitudinal at the beginning of the cardiac part and the pyloric part with net-work between the folds. The stomach communicates with the intestine through the valve at the end of the pyloric part, forming deep longitudinal folds. No intestinal winding, except that the duodenum curves in U-shape, intestine short (the length being ca. 1.7 as long as d~a), rather wide, wall thick, mucous membrane of the duodenum presents a net work of papillae (Pl. X, Fig. 16), while that of the middle intestine forms transversal folds similar to the Plica Kerckringi of the human being (Pl. X, Fig. 9). Pyloric appendages, regular in length and width tips pointed, 150 in number or thereabouts. The opinion on the number seems to differ somewhat among the scholars. For instance: Jordan and Evermann (1896) say 80; Tanaka (1921) 140 to 185; Ôno (1928) 130 to 200; Kawakami (1934) 105 to 225.

Liver consists of 1 lobe, located to the left of the digestive organs, and covers a part of the pyloric appendages. Gall-bladder almost spherical, situated to the right of the liver and extends to the lower cardiac part. Spleen situated at the curve of the stomach. Pancreas located along the curve of the stomach, along the intestines, and between the pyloric appendages; rather large, white, spherical islets of Langerhans sparsely scattered.

B. Feeding Habits.

Regarding the food of the dog salmon at sea, it was evident from the studies which Marukawa (1919) made of the stomach contents of those collected from the waters around Kamchatka, that its main food consists of small animals, such as small Crustacea, larvae of crabs, Pteropoda, etc., and the Hokkaidô Fisheries Experimental Station, who are putting forth their best efforts in the ecological observation of Salmonoid fishes, reported in 1929 that the principal food of the dog salmon was schizopods, young herrings and jelly-fishes. The 1934 report gave an analysis of the natural baits of fishes in the waters around Kusiro and Syakotan, in which it explained that a large quantity of copepods constituted the food.

The material which I treated in this connection were, to my regret, few, but as a supplement to the above studies and grounds for further discussion, I am giving the results of my investigation.

It will be seen from Table 6 that the food of the dog salmon caught off

Table 6

Stomach contents of *Oncorhynchus keta*. *O. nerka*. *O. masou*

Sample	Date	Locality	Sex	Number of fish	Stomach contents
O. keta	July 16, 1930	Ozernaya	♂	3	Certain Amphipoda, *Anonyx* sp., certain Crustacea, bones of young fishes, none (1)
			♀	3	*Parathemisto oblivia*, none (2)
	Aug. 14, 1930	South Ozernaya	♂	2	Certain Amphipoda, *Siriella* sp., *Anonyx* sp., zoëa larvae
			♀	2	Certain Schizopoda, Polychaeta larvae
O. nerka	July 2, 1930	Bristol Bay	♂	4	Certain Copepoda, zoëa larvae, certain Polychaeta, *Thysanoessa raschii*, bones of young fishes, *Stelgistrum* sp. (Ottosei-kazika)
			♀	2	*Thysanoessa raschii*
	July 16, 1930	Cape Ozerni	♀	2	Zoëa of *Erimacrus isenbeckii* (Kegani)
	July 21, 1930	West Kamchatka	♂	3	Zoëa larvae, youngs of Clupeidae, none (1)
			♀	1	Zoëa larvae
	July 16, 1932	Sibotu Island	♂	1	Youngs of Clupeidae
			♀	2	Zoëa larvae, none (1)
O. masou	July 18, 1932	Ibid.	♂	3	*Parathemisto oblivia*,. youngs of *Osmerus* and Clupeidae
			♀	3	Certain Amphipoda, certain Copepoda, zoëa larvae, bones of young fishes

the coast of Ozernaya and South Ozernaya consists chiefly of Amphipoda, Schizopoda, zoëa larvae, and Copepoda; and that Polychaeta and young fish were found only once among the stomach contents of this fish during this analysis. I mention this as a matter of interest because it agrees with the general opinion expressed by the foregoing scholars that the main food of the dog salmon at sea was the planktonic micro-crustaceans. It would seem that the nature of this fish is somewhat milder than the other fishes of Salmonidae. According to Marukawa, the male in general is a heavier eater than the female.

10. *Oncorhynchus nerka* (Walbaum): Benimasu.

A. Digestive System.

I studied with material collected around the waters in Kamchtka. As the form of the body and other details are similar to those of the dog salmon, I shall not go to any lengthy description but simply give the different points.

Mouth moderately large, varies somewhat according to the male and female at the period of fecundity but little difference in the size (m-c being about the same as in the female dog salmon). Teeth on the jaws, vomer, palatines and the tongue; the vomer teeth of the male developing even after maturity. The size and form of gill-rakers are similar to those of the dog salmon in the previous chapter, the number being somewhat larger, 32 to 44. Contrary to this, the number of the pyloric appendages is somewhat less, 80 in average.

The form of the stomach, intestinal winding and folds of the mucous membrane are all similar to the species in the previous chapter, the middle intestine having distinct transversal folds.

B. Feeding Habits.

As far as I have been able to ascertain, the only report on the feeding habits of this fish was written by Marukawa (1919). At the same time he studied the dog salmon, he collected quite a number of the present species and examined its stomach contents, when he found that the two species had several points in common, that is, both fed on minute Crustacea or Heteropoda and were not of the carnivorous and voracious in nature. From my observation of the material obtained, there was not much difference in the result obtained by Marukawa, namely, as shown in Table 6, their chief food being Crustacea, such as Schizopoda and larval crabs, and no substantial amount of larval or young fishes had been taken.

As for the food of land-locked *Onchorhynchus nerka* (i. e., *O. adonis*: Himemasu), Kawamura (1928) who examined the stomach contents of the Himemasu in Lake Aoki, found that during the period of winter and the beginning of spring, its principal food was *Diaptomus* which is found in the middle stratum of the lake; from spring to summer *Cyclops* and larval mosquitoes; and from summer to autumn *Daphnia*. Higurasi, Kawaziri and Hata (1931) made the same study at the same place and obtained almost the same results. Takayasu, Igarasi and Sawa (1930) made the same observation with those collected in Lake Akan and discovered that their principal food was *Daphnia* and *Diaptomus*. Further, Hata and Simogawa (1931) ascertained that the food of the Himemasu in Lake Noziri was generally Copepoda and Cladocera and, sometimes, *Tribolodon hakonensis* and shrimps. Takayasu and Kondô (1934) found that those in Lake Tôya fed chiefly on *Daphnia* and *Cyclops*, only that the female was the bigger eater. Very recently, Matui and Wadauti (1937) examined the stomach contents of the Himemasu collected in various localities of Lake Towada, and found that although the constitution of food matters differed according to the fishing grounds, its staple food consisted of Copepoda, Rotatoria, larvae of Chironomidae and other insect larvae.

11. *Oncorhynchus masou* (Brevoot): Masu.

A. Digestive System.

I studied the digestive system of this fish collected from the adjacent waters of Sibotu Island, Tisima. Mouth moderately large, hardly any difference between the male and the female. Teeth generally smaller than those of the dog salmon; minute teeth on the jaws, vomer and palatines. Gill-rakers thick and short, numbering 16 to 22. Pyloric appendages comparatively narrow and long, 40 to 45 in number. Both the gill-rakers and pyloric appendages are less in number than the 2 previous species. The rest, the form of the tongue, the digestive tract, etc. are practically the same as the 2 foregoing species.

B. Feeding Habits.

The report of Marukawa (1919) is the only literature that may be found on the sea food of this fish. According to Marukawa, the principal food of this fish is also about the same as the 2 foregoing species, only that it is a trifle bit voracious in its feeding and goes in pursuit of small fishes. In his report he gives *Osmerus* as one of the food items of this fish, which was not taken at all by the foregoing 2 species. I also have ascertained that this fish is much more voracious and carnivorous than the other 2 species. There are many reports on the food of trouts in fresh water As far as I know, however, reports regarding the natural baits of *Oncorhynchus masou* are as follows: Kawamura and Maeda (1914) examined the stomach contents of those collected at the Marunuma Experimental Station, Sigaken, and ascertained that they consisted of Copepoda, Cladocera. Ostracoda and insect larvae all the year round.

12. *Salvelinus leucomaensis pluvius* (Hilgendorf): Iwana.

A. Digestive System.

Body moderately elongate, compressed; head short; nostrils close together. Mouth rather large, (m-c and m-b both being ca. 1/3 of head length), oblique, the upper jaw being slightly longer than the lower. A row of small conical teeth on the jaws, vomer, and palatines, which curve toward the throat. Buccal cavity tolerably large, the palatal mucous membrane consisting of longitudinal folds. Tongue trapezoid, large, free, a groove in the center and a row of conical teeth, facing the throat, on each side of the groove; no melanin chromatophores. Pharyngeal teeth degenerated. The gill-rakers of this fish possess the characteristics of Salmonidae, there not being much difference between those of the trout and salmon; about 17 in number.

Peritoneal cavity rather large: just a few melanin chromatophores in the peritoneum. Stomach large, U-shape, wall thick, the mucous membrane of which consisting of 9 to 10 longitudinal folds and a net-work between them. Intestine short (the length being ca. 1/3 of d~a), the part corresponding to the duodenum curving in shape U, broad, wall thin, the mucous membrane of which consisting of net work and transversal folds. Pyloric appendages rather long, arranged almost in a row, 11 in average number.

Liver small, consisting of 2 lobes which appear almost 1, the left and right being approximately the same size. The cardiac part of the stomach is on the ventral side. Gall-bladder

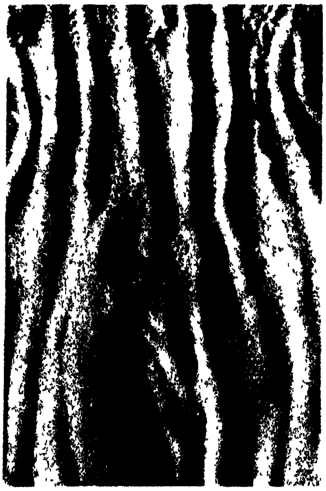


Fig. 26. *Salvelinus leucomaenis pulvius.* Folds of mucous membrane of stomach.

rather large and spherical; bile duct short. The spleen, small, is located right next to Fundus ventriculis.

B. Feeding Habits.

With regard to the natural baits of the Iwana, in March and April 1928, Kuwayama (1929) collected quite a number of this fish (including the Amemasu) in Nisibetu River, Kusiro, Hokkaidô, and examined its stomach contents. He found that a large portion of the stomach contents contained larvae of aquatic insects, especially Tricoptera (Limnophilidae, Sericostomatidae, Leptoceridae, Philopotamidae, and Rhyacophilidae), in their larval stage came first insofar as quantity was concerned. He concluded his report by saying that attention should be drawn to the feeding habits of this fish which ate a large quantity of Tricoptera which was detrimental to rice-plants. In the summers of 1932 and 1933, Nisio (1934) also examined the stomach contents of the many samples he had collected in the up-stream of Sôunkyô, Isikari, Hokkaidô. He advocated the view that this fish was purely carnivorous in its feeding habits and fed chiefly on insect larvae and nests. At the time of his examination, Coleoptera, Trichoptra, Diptera, Ephemeroptera, Hymenoptera, Plecoptera, and Lepidoptera, etc. were found among the contents.

In the summer of 1937, through the courtesies of Mr. T. Mizukami, I was able to examine the stomach contents of 15 pieces of this fish collected from a river in Kamibayasi, Nagano Pref., but as the results of this examination were more or less the same as the foregoing, so I decided to omit them here.

Family PLECOGLOSSIDAE

13. *Plecoglossus altivelis* (Temminck et Schlegel): Ayu.

A. Digestive System.

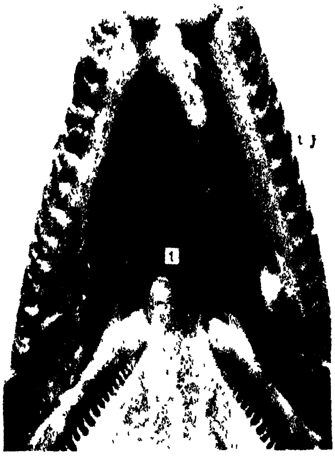


Fig. 27. Lower jaw of *Plecoglossus altivelis.*

Body moderately elongate, somewhat compressed. Mouth moderately large (m-c being ca. 1/2 and m-b ca. 1/3 of head length), slightly oblique upwards; lip of the upper jaw turns vertically down and the lip of the lower vertically up; upper lip slightly projecting than the lower. On the premaxillaries a few small conical pointed teeth; on the maxillaries and in the lower jaw 14 sets of lamelliform, broad, comb-like teeth. Each tooth-band consists of about 15 tooth-like processes in a row. Buccal cavity small; Plica palatinae separate, wart-like process. No teeth on vomer but small ones on the palatines. Tongue very small, trianguloid, tip not pointed, thin, free, with minute teeth, no melanin chromatophores (Pl. III, Fig. 10). The "tongue-lappen", so called by Matui

(1936), which locate at the front and both sides of the tongue well developed. According to Matui, this consists of the epithelium connective tissue and muscular tissue. From my observation, what he calls the " lateral tongue-lappen " is the Musculi hypobranchiales. The pecularity of the jaw teeth and the existence of the tongue-lappen in the jaws of this fish are the two major points which differ from the other fishes. Teeth on the tongue and the pharyngeal bones are simply rudimentary. Gill-rakers short (the length of which being ca. 1/3 of corresponding gill-filaments), slender, set rather close together, 34 to 39 in number, flat, tips pointed, processes not developed.

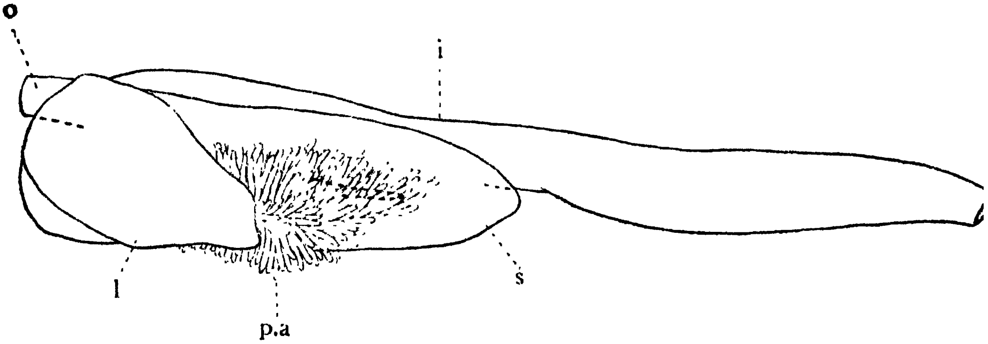


Fig. 28. *Plecoglossus altivelis.*

Peritoneal cavity rather large; peritoneum thin and black. Oesophagus moderately long, narrow, wall not thick, mucous membrane forming ca. 10 longitudinal folds. Stomach V-shape, no blind sac; cardiac part longer than the pyloric part, the wall of the former being thinner than the latter. No valve between the oesophagus and the cardiac part of the stomach but contrary to the former being narrow, the latter is wide. As for the mucous membranes of the stomach, both the cardiac and pyloric parts consist of about 8 longitudinal folds, and between these folds there are many small papillae insofar as the cardiac part is concerned and many fine longitudinal folds as far as the pyloric part is concerned. Intestine short (the length being ca. 1.3 times as long as d~a), rather broad, the part equivalent to the duodenum making 1 big curve, wall thin, folds of the mucous membrane transversal. No difference between the rectum and intestine. Pyloric appendages, a mass of short clusters, numbering 350 to 400, situated to the left of the stomach.

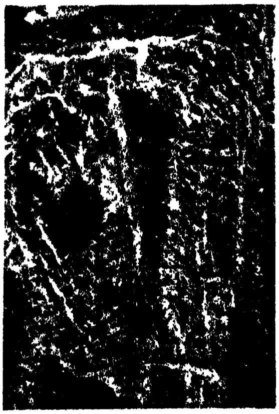


Fig. 29. *Plecoglossus altivelis.* Folds of intestinal mucous membrane.

Liver thick and rather small, 1 lobe, situated to the left of the stomach, and covers the front part of the pyloric appendages. Air-bladder large, narrow at both ends, expanding at the middle.

B. Feeding Habits.

This fish is peculiar to Japan. It is a graceful fish, as well as being delicious in taste, and, from ancient times, has been a favourite among anglers. The habits of this fish attracted attention from olden times, and already in 1715, Kaibara wrote in his "Yamato Honzô", Vol. 13, p. 31, that the ayu in rivers with rocky and stony beds, lived on "koke" (water-moss) on the stones. At the end of the 19th century, Nawa (1891) said that the reason for there being so much diatoms in the stomach contents of this fish was due to their feeding on the water moss which was mixed with a large quantity of diatoms. In addition to this report, there is a report by Namie (1895) who said that this fish fed on small water plants and diatoms, as also by Tokuhisa (1908) and Onizuka (1915) who advocated the principal food of the ayu in the rivers Tama and Kuma respectively as being the diatom. All these people seem to believe that this fish feeds principally on vegetable food, such as the diatom. But Suminiti (1912), who examined the stomach contents of the ayu caught in several different rivers, asserted that the main food of this fish consisted of animal matter, and that vegetal matter, such as the diatom, got mixed into its food when it was feeding. Higurasi (1917) studied the food of the ayu in the Yodo River and expressed the opinion that when it first entered the river it fed on insects, but as it went upstream, it began to feed on vegetal matter off rocks and stones. Inasumi (1932) maintained that the diatom, the staple food of the ayu, was a food which it could not do without, because the diatom contained a large percentage of vitamin "E" which gave that special smell to the meat of this fish. Also, Abe (1933) took up briefly the description of the natural food of this fish in his book.

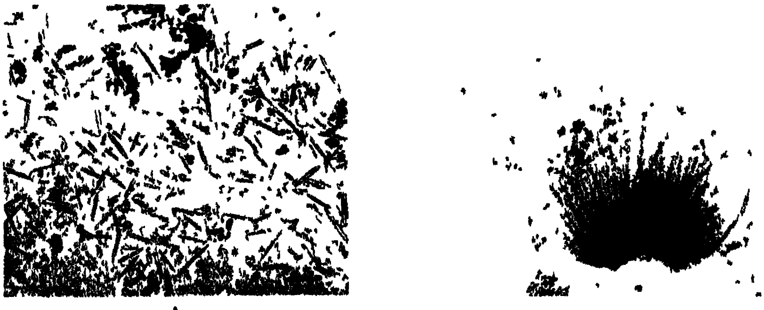


Fig. 30. Stomach contents of *Plecoglossus altivelis*. (After Ueda and Okada). A. Mainly diatoms. B. Mainly blue-green algae.

All the foregoing reports discuss the food of the ayu on the merits of personal observation of those collected in 1 or 2 different localities or personal opinions formed resulting from these observations, but very recently Ueda and Okada (1934, 1935) completed a study of the natural food of this fish in all the localities of Japan and made 3 separate reports. According to their report, the main food of the adult ayu, that is, when it first enters the river, is the diatom and vegetal food, such as the blue-green algae, green and red algae, but the few that live in special places, that is to say, where there are no food such as those mentioned above, live chiefly on insect larvae. The young of this fish, while at sea, takes animal food, such as Copepoda, Cladocera and the like, but when it becomes a full size fish and enters the river, it switches over to herbivorus food, which is not only a well known fact but which I have ascertained personally with the young caught in the Odawa Bay, Kanagawa Prefecture, and which has actually been studied by several biologists in the past.

Family OSMERIDAE

11. *Hypomesus olidus* (Pallas) : Wakasagi.

A. Digestive System.

Body rather elongate, moderately compressed. Head rather pointed. Mouth moderate (m-c being ca. 1/3. m-b being ca. 2/9 of head length), slightly oblique, Minute teeth exist in jaws, and larger teeth grow in 2 series on vomer and palatines. Buccal cavity moderate; tongue large, long, thin, triangular, armed with numerous sharp teeth, free anteriorly. No pharyngeal teeth. Gill-rakers long (as long as corresponding gill-filaments) are slender, close set, tip rather pointed, 35 to 38 in number.

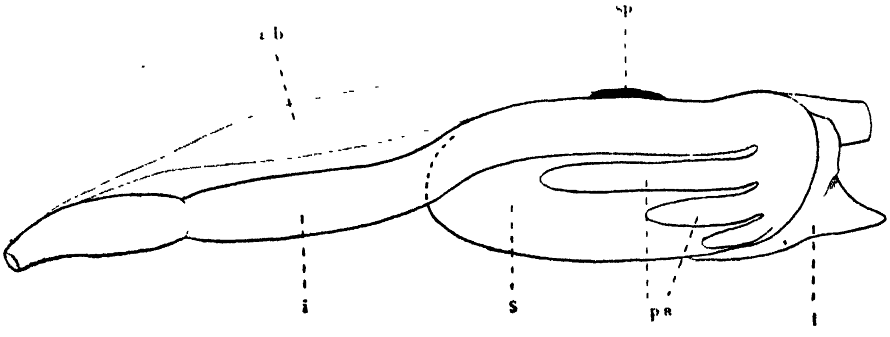


Fig. 31. *Hypomesus olidus.*

Peritoneal cavity moderate; peritoneum black. Oesophagus short with thick wall, the mucous membrane consists in longitudinal folds. Stomach assumes U-shape, wall not thick, the mucous membrane of cardiac part consists in 10 series of papillae and that of pyloric part consists in common longitudinal folds (Pl. VI, Fig. 6). Intestine short and rather wide, running almost straight at the right side of stomach towards the anus, the length of which being ca. 1 in d~a, wall thin. Intestine is divided into the middle intestine and the rectum, the length of the former being ca. 4 times in the latter; there is a constriction between those two parts. Pyloric appendages short and wide, located at the right ventral of the stomach, 5-6 in number.

Liver moderate and rather thick, 2 lobes, the left being much larger than the right; gall-bladder small, spherical, Ductus choledochus short. Air-bladder large, fusiform, anterior part of which communicates at the end of oesophagus. Spleen small, situates at the dorsal side of the cardiac part of stomach.

B. Feeding Habits.

Regarding the natural food of *Hypomesus olidus*, the Ibarakiken Fisheries Experimental Station made the original report in the year 1910. Takayasu and others observed the stomach contents of those fishes which were collected from Lake Tôfutu (1930) and Lake Yutô (1934) in Hokkaidô, and found that the fishes in the former lake took mainly the copepods and *Mysis* and those the latter took principally *Neomysis isaza.*

Lately, T. Miyauti collected 20 fishes every month from Lake Kasumigaura in 1933 and 1934, and examined their stomach contents. He ascertained that *Hypomesus olidus* took mostly on such kinds of small animals, especially the planktonic Crustacea, as were found most abunduntly in the lake. *Bosmina* and *Neomysis* were numerous therein all the year round and took by the fish irrespective of the seasons. In 1931, by the courtesy of Mr. H. Sinohara, I was able to obtain 15 fishes from a bay of Sibotu Island, Tisima. Analysis of their stomach contents showed that they ate the planktonic Crustacea such as *Calanus tenuicornis*, *Anonyx* sp., *Thysanopoda* sp.

Family SALANGIDAE

15. *Salangichthys microdon* (Bleaker): Sirauwo.

A. Digestive System.

Body elongate, compressed; snout somewhat pointed and depressed. Mouth not large (m-c being ca. 5/16, m-b ca. 2/7 of head length). Teeth in jaws numerous, very small, conical. Rudimental teeth on palatines, but none on vomer. Buccal cavity depressed; tongue large, rectangular, rather thick, free, smooth, no melanin chromatophores. Gill-rakers rather long (as long as corresponding gill-filaments) and slender, tips pointed, 16–18 in number. No pharyngeal teeth.

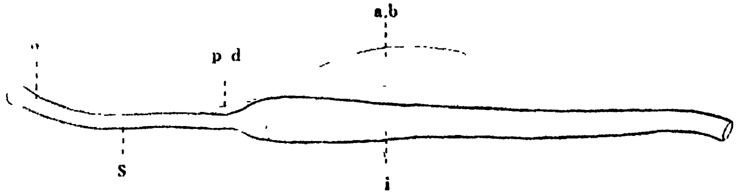


Fig. 32. *Salangichthys microdon.*

Peritoneal cavity long, a few melanin chromatophores scattered in peritonium. Digestive tract runs almost straight from oesophagus to anus, and intestine twice the width of stomach, there is a valve between stomach and intestine. Stomach being ca. 1/2 of the length of intestine, wall of which rather thick, the mucous membrane consists of 9 longitudinal folds. Intestine short (as long as d~a), decreases its width toward anus, the mucous membrane consists of distinct transversal folds. Boulenger (1922) stated in his book (p. 566) that the fishes belonging to the family Salangidae had siphonal stomach and had no pyloric appendage.

Liver moderate in size, thick, consists of symmetrical 2 lobes, the cross section of which assumes U-shape. Air-bladder fusiform, Ductus pneumaticus opens at the end of stomach.

B. Feeding Habits.

According to the report made by Wakiya and Takahashi (1937), the food of *Salangichthys* consists of Micro-crustacea.

Family SYNODONTIDAE

16. *Saurida undosquamis* (Richardson): Maeso.

A. Digestive System.

Body moderately depressed. Upper jaw a little longer than the lower. Mouth large (m-c being ca. 2/3, m-b ca. 2/5 of head length); teeth in jaws small, conical and pointed, arranged irregularly 2 or 3 rows; vomer and palatines armed with similar teeth. Buccal cavity not large, depressed, tongue very small, thick, triangular, teeth which are smaller than those in jaws grow in 4 rows, each row contains ca. 18 teeth on the upper surface. Teeth on upper and lower pharyngeal bones are shorter than the jaw teeth. So-called gill-rakers not develop, and represented by a few small group of setae.

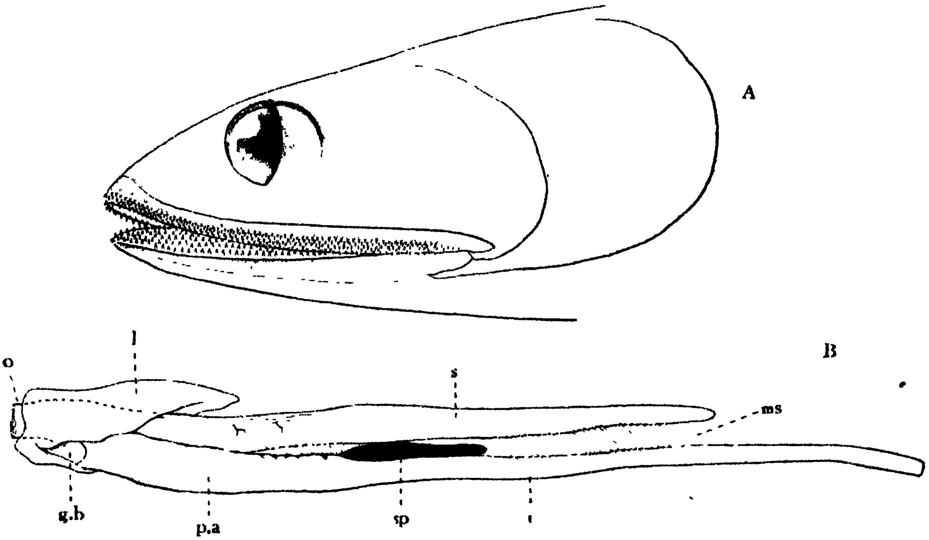


Fig. 33. *Saurida undosquamis.* A. Head. B. Digestive tract.

Peritoneal cavity rather large; peritoneum thin, rich in melanin chromatophores. Oesophagus short, wall thick; stomach ˥-shape, blind sac long tube, cardiac part short and pyloric part shorter; the wall of stomach is so thick that it stands fully for the enlargement. Intestine short, rather narrow, runs almost straight from duodenum to anus at the right side of the blind sac, wall moderately thick, the mucous membrane consists of double branched folds. Pyloric appendages consist of about 20 flat bunches arranged in 1 row, closely set, covered with a membrane. According to Matsubara (1938), the pyloric appendages of Genus *Synodus* (the fishes nearly related to the above mentioned species) are separated, as in the case of many other fishes.

Liver rather thick, consists of 2 lobes, the left one being a little longer than the right; gall-bladder spherical, located at the boundary between those 2 lobes; Ductus choledochus short. Air-bladder absent.

B. Feeding Habits.

Judging from the results of my experiment (See Table 7), we can with a certain degree of probability reckon that this species is voracious carnivora.

Table 7

Stomach contents of *Saurida undosquamis*

Date	June, 1936	July 20, 1931	Frequency
Locality	Ogôri, Yamaguti Pref.	Kyôto Fish Market	
Number of fish	20	20	
Body length (cm)	15~30	–	
Body weight (g)	36~401	–	
♀:♂	6:14	–	
Stomach contents (0.2 to 19 g.)			
Katakuti-iwasi (*Engraulis japonicus*)	6		6
Ma-eso (*Saurida undosquamis*)	1	1	2
Kurakakegisu (*Neopercis sexfasciata*)	1		1
Pleuronectidae	3		3
Cottidae		1	1
Shrimps		6	6
Akaebi (*Erithropenaeus akayebi*)	3		3
Loligo kobiensis	2		2
Mud		1	1
None	4	7	11

Family MYCTOPHIDAE

17. *Dasiscopelus spinosus* (Steindachner): Ibarahadaka.

A. Digestive System.

Body elongate, a little compressed (with photophores). Mouth large (m-c being ca. 4/7, m-b ca. 2/5 of head length), somewhat oblique upwards. Setiform teeth grow in narrow band in jaws; no teeth on vomer and palatines. Buccal cavity large; tongue absent. Gill-rakers long (the length being ca. 3/2 of corresponding gill-filaments), flat, tips pointed, grow thickly, 18 to 20 in number, process numerous.

Peritoneal cavity moderate in size, peritoneum black. Oesophagus short with thick wall, the mucous membrane consists of 6 to 7 longitudinal folds. Stomach moderately large with thick wall, Y-shape; blind sac small and pyloric part moderate in size, the mucous membrane of stomach similar to that of oesophagus. Intestine not long (the length being ca. 1.3 times d~a), turns once in r-shape, wall thin and black, the mucous membrane consists of papillary processes. Pyloric appendages rather long, 9 in number, situated at the left of stomach.

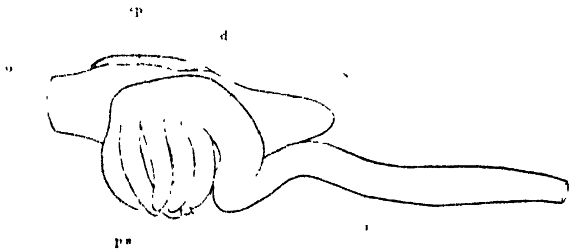


Fig. 31. *Dasiscopelus spinosus.*

Liver situates under the stomach, consists of a large right lobe and a small left one; gall-bladder small, spherical. Air-bladder fusiform, the posterior end of which communicates to the oesophagus.

B. Feeding Habits.

In the summer of 1934, during the voyage of fishing for bonito, I caught 25 of these adult fishes at night, about 200 miles off the coast of Tyôsi. They had taken fully the schizopods in their stomachs.

Family CYPRINODONTIDAE

18. *Aplocheilus latipes* (Temminck et Schlegel): Medaka.

A. Digestive System.

In regard to the special method of examining the digestive system of this fish, I have already written regarding it.

Body small, rather elongate and compressed; head short, broad, upper surface flat. Mouth rather pointed, small (m-c being ca. 1/16, m-b ca.

1/4 of head length), slightly oblique, upwards; lips rather thick. Teeth in the jaws few and minute but sharp. Buccal cavity moderately large. Plica palatinae consist of small papillae. Tongue very large, rectangular, almost triangular at the tip, moderately thick, free, no melanin chromatophores, translucent, surface not smooth. Gill-rakers closely set, short (the length of which being ca. 1/3 of corresponding gill-filaments), tips rather pointed, the number of which ca. 19.

Peritoneal cavity large; peritoneum silvery. Oesophagus short, with rather thick wall. Stomach U-shape (although there is no clear distinction between the stomach and the intestine, the stomach is a rather thick, U-shape tube, while the intestine is a tube trifle narrower than the former), wall thin, no blind sac. Intestine broad and fairly long (the length being ca. 5 times o~a), and so curious in the way it winds, to let alone the curiousness of the intestine of *Engraulis japonicus*. As shown in the illustration, it is the result of the intestine running in a series of waves curling over an imaginary line running longitudinally from front to back, that is, the highest part of the wave curls down while the lowest part curls up. At a glance it seems to be a coiling, but upon closer observation, it will be seen, as explained above, that it curls up in a peculiar way of its own.

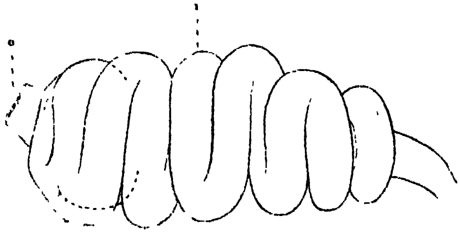


Fig. 35. *Aplocheilus latipes*.

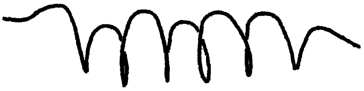


Fig. 36. *Aplocheilus latipes*. Intestinal winding.

Wall of the intestine very thin; mucous membrane indistinctly wavy, transversal folds. Pyloric appendages absent. Liver, consisting of 1 lobe, situated at the ventral side of the stomach.

As regards the digestive tract of this fish, Okamoto (1918) wrote a report on it sometime ago. He pointed out the difficulty of distinguishing the stomach and the intestine, but said nothing about the peculiar type of winding of its intestine. However, Cuvier in his "Histoire naturelle des poissons", Vol. 18, p. 140, wrote about the intricate windings of the intestine of *Fundulus caenicatus*. There are several persons who made a study of the digestive system of *Fundulus*, but I shall not mention them here.

B. Feeding Habits.

This fish, which has its habitat in rivers, generally goes schooling in pursuit of food near the surface of the water. In July and September of 1936, I collected a total of 37 fishes in a river in Ogikubo, Tokyo, and upon examination of their stomach contents, I found that their main food was either blue-green algae or planktonic Crustacea, although, if compared, there was more of the former. As for the feeding habits of *Fundulus*, I have already stated that they were being studied with those of *Gambsia* as to whether or not it took larval mosquitoes which were the medium of malaria.

Family SILURIDAE

19. *Parasilurus asotus* (Linné): Namazu.

A. Digestive System.

Body spindle-shape, anteriorly depressed and posteriorly compressed. Mouth large (m-c being ca. 2/7, m-b ca. 2/3 of head length), directed obliquely upwards; the lower jaw being longer than the upper. Teeth in both jaws in broad villiform bands, and those on the vomer in broad continuous; maxillary barbels long, 2 in number. Barbels of catfish are most common among the barbels of fishes and naturally have been more popular as an object of study, and such scholars as Wright (1881), Herrick (1901, 1903) and Olmsted (1918) studied the barbels of foreign catfish, while Atôda (1935) those of Japanese catfish. Mouth cavity large; tongue large, semi-circular, thick, free anteriorly, the surface folded, no melanin chromatophores. Upper pharyngeal teeth large and the lower small, both of which being closely set. Gill-rakers short (the length being ca. 1/5 of corresponding gill-filaments), tips pointed, very coarse, 11 to 13 in number (Pl. IV, Fig. 3).

Peritoneal cavity large; no melanin chromatophores on the peritoneum. Oesophagus very wide with a thick wall, mucous membrane consisting of about 30 fine longitudinal folds. Stomach large, I-shape, wall thick, mucous membrane constituting of 8 longitudinal folds; pyloric part and blind sac both rudimentary, with valve dividing the stomach (pyloric part) and the intestine.

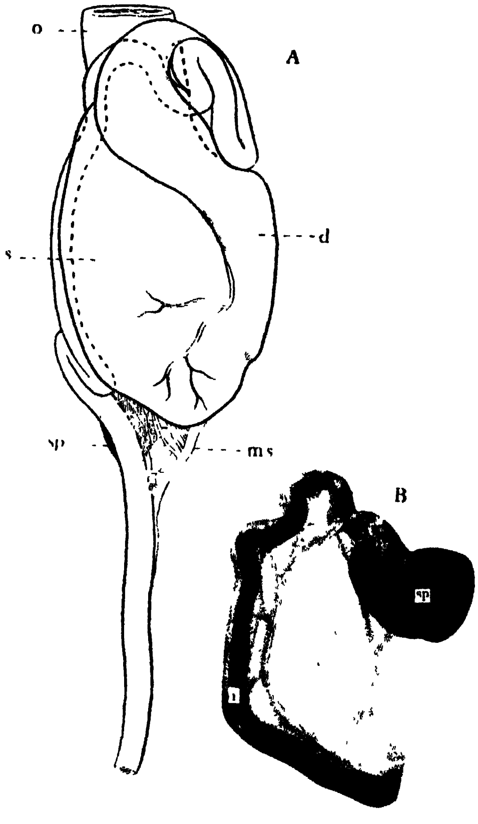


Fig. 37. *Parasilurus asotus.* A. Digestive tract. Ventral side. B. Mesentery.

Although of the same family Siluridae, *Parasilurus* has a stomach but *Plotosus* in the next chapter has not, which is worthy of note. Duodenum wide; intestine very narrow; the length of the duodenum plus the intestine, being about 3 times d~a. Wall of intestine thick, mucous membrane consisting of somewhat zigzag longitudinal folds with numerous transverse folds between them. As illustrated, the intestine makes numerous short turnings; mesentery rather thick and wall developed. No pyloric appendage.

Liver rather large, consisting of a large left lobe and a small right lobe, covers the anterior part of the stomach from above; gall-bladder rather large, spherical; bile and cystic ducts both very short. Spleen thin, situated more or less near the end of the intestine. Air-bladder large, sack-like, wall thick.

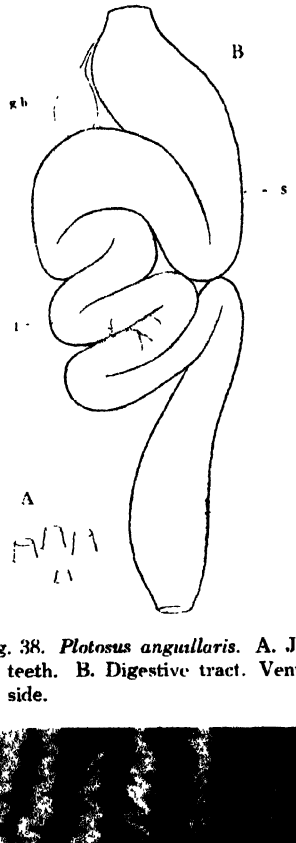


Fig. 38. *Plotosus anguillaris*. A. Jaw-teeth. B. Digestive tract. Ventral side.

Fig. 39. *Plotosus anguillaris*. Folds of mucous membrane of stomach.

B. Feeding Habits.

It is well known that this fish is voracious and likes to live in shadowy spots. In October 1934, I obtained 14 of this fish from Kasumigaura, Ibaraki Prefecture, 8 of which had empty stomachs but the rest showed having eaten small fishes and shrimps. "Pokan-zuri" is done by baiting the line with live frogs and tapping the surface of the water, which method of fishing is in line with the feeding habits of this fish.

20. *Plotosus anguillaris* (Lacépède): Gonzui.

A. Digestive System.

Body elongate, compressed. Head large, broad, depressed. Mouth very wide (m-c being ca. 1/8, m-b ca. 1/2 of head length); upper jaw produced and mouth opens somewhat downward. Teeth in jaws few and rather large, cylindrical, grow coarse in 3 to 4 rows; similar teeth exist on vomer and palatines. Lips rather thick, fleshy and with small laminated folds or papillae. Satô (1937) found that this fish possesses 8 barbels about the mouth with the same form and structure as the foregoing species, and among the epidermal cells of the barbels, the cutaneous taste-buds were imbedded. By the experimental observations in an aquarium, he found that the barbels of this fish useful for finding its food, as in the cases of the above-mentioned fish and the Japanese goat-fish, *Upenoides bensasi*. Buccal cavity large; tongue large, semicircular, the size closely resembling that of the foregoing species, thick. Pharyngeal teeth subsimilar to those of jaws, grow in a pair of cluster on the upper and lower pharyngeal bones. Gill-arches much bent, gill-rakers moderately long (a little shorter than corresponding gill-filaments), not slender, tips somewhat blunt, grow rather closely, the number of which ca. 23.

Peritoneal cavity large; peritoneum grey. Oesophagus short and wide, wall thick, the mucous membrane consists of ca. 30 longitudinal folds. Stomach absent: intestine succeeds directly to oesophagus. The beginning of intestine bulgy, and apt to be taken for the stomach; melanin chromatophores scattered in this part. Intestine generally broad and turns snaky 6 to 7 times from side to side; rectum rather long and wide; the mucous membrane of intestine consists of about 7 rows of papillary processes. The length of the digestive tract including the oesophagus, the intestine and the rectum beiug ca. 2 to 2.5 times o~a. Pyloric appendage absent.

Liver small, 2 lobes, located at the lower part of the beginning of the intestine. Gall-bladder moderately large, spherical; bile-duct short, opens at the beginning of the intestine. A pair of spleen (large and flat) located at the dorsal side of the digestive tract. Air-bladder large, squre in shape, wall thick.

Cuvier and Valenciennes describe in their book (Vol. XV) on the digestive tract of *Plotosus lineatus* that it has no stomach, and its intestine makes the serpentine winding.

B. Feeding Habits,

I examined the stomach contents of 27 fishes which were caught from Koaziro Bay near the Misaki Marine Biological Station, Kanagawa Pref.. The contents consisted of mainly the eggs of some fishes and cuttle-fishes, and the spores of sea-weeds, etc. According to Satô (1937), this fish is a bottom and nocturnal feeder.

Family CYPRINIDAE

21. *Gnathopogon caerulescens* (Sauvage): Moroko.

A. Digestive System.

Body elongate and compressed. Head rather pointed; mouth small (m-c being ca. 1/5 of head length, m-b a little longer), slightly oblique upwards. A pair of barbel short. No teeth on jaws, vomer, palatines and tongue. Buccal cavity rather small; tongue small, triangular and long, not free, mucous membrane which covers the tongue thick with curved transversal folds, no melanin chromatophores. Pharyngeal teeth 2-rowed, conical processes (or teeth) grow on their grinding surface. Gill-rakers very short (the length being ca. 1/6 of corresponding gill-filaments), tips pointed, grow coarse, 22 in number.

Peritoneal cavity moderately large, peritoneum silvery mixed with large melanin chromatophores. Oesophagus broad and rather long, clearly distinguished from the intestine succeeding it by the folds of their mucous membranes: the former assumes genuine longitudinal folds, while the latter longitudinal zigzag ones. Stomach absent (this is one of the special characters of

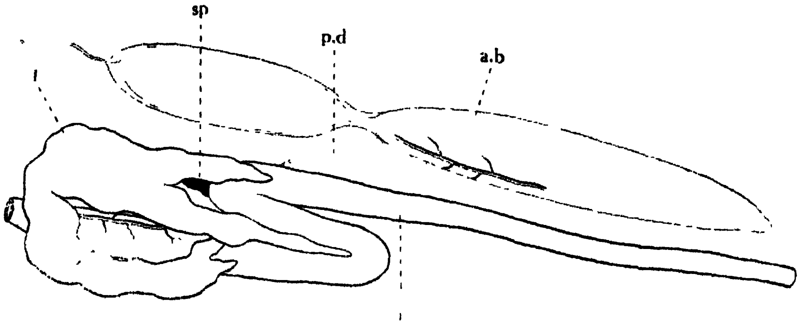


Fig. 40. *Gnathopogon caerulescens.*

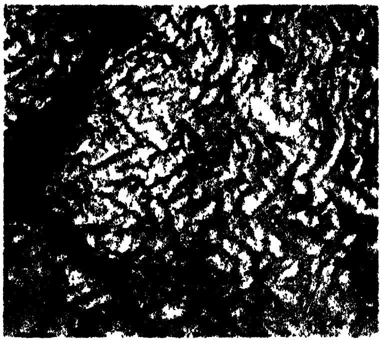


Fig. 41. *Gnathopogon caerulescens.* Folds of mucous membrane of intestine.

the Cyprinoid fishes). Intestine narrow, rather short (the length being ca, 3/2 of o~a), bends twice, viz. N-shape, wall rather thin. No pyloric appendage.

Liver takes more or less the irregular form, not mixes with pancreas; spleen small, located near the second bending part of intestine. Air-bladder large, dumb-bell-shape, pneumatic duct starts from the middle part of the air-bladder and communicates to the end of oesophagus.

B. Feeding Habits.

According to the report made by Meguro (1934), this fish takes usually the roots of water-plants, small shrimps and insect larvae, etc., viz. omnivorous.

22. *Sarcocheilichthys variegatus* (Temminck et Schlegel) : Higai.

A. Digestive System.

This fish closely resembles in the form of the digestive system the above-mentioned species, yet there are some differences between the two species as follows:—head bluntly pointed; pharyngeal teeth 4 to 5, arranged

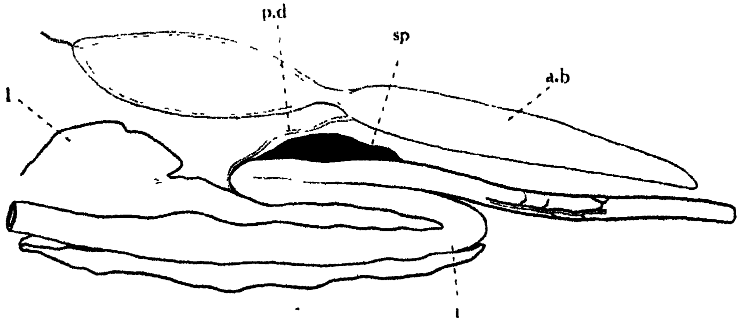


Fig. 42. *Sarcocheilichthys variegatus.*

in 1-row; gill-rakers a little shorter, 7 in number; intestine a little longer (the length being ca. 5/3 of o~a).

B. Feeding Habits.

Regarding the food of this fish, it is evident from the study which the Sigaken Fisheries Experimental Station (1928) made of the stomach contents of the fish collected from the lake Matubara, Siga Prefecture, that its main food consists of small animals, such as the larvae of Trichoptera or Plecoptera, the adults of Coleoptera, some shrimps and small vegetables, such as the diatoms.

23. *Tribolodon kakonensis* (Günther): Ugui.

I have already made a report (1934) on the digestive system and the feeding habits of this fish.

A. Digestive System.

Body elongate and compressed. Mouth moderately large (m-c being ca. 2/7 of head length, m-b approximately the same size), curving slightly upwards: maxillary protractile; lips fleshy. No teeth on jaws, vomer, palatines and the tongue. The shape and size of the tongue about the same as those of the 2 foregoing species. 2 rows of pharyngeal teeth with grinding surface. Gill-rakers short (the length being ca. 1/3 of corresponding gill-filaments), flat, slightly curved, tips pointed, coarse, 9 to 12 in number.

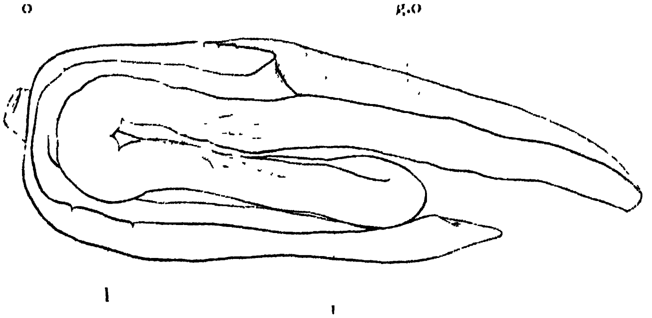


Fig. 43. *Tribolodon hakonensis*

Peritoneal cavity moderate; peritoneum pale grey with a few melanin chromatophores. The digestive tract consists of short oesophagus and a rather short intestine. No stomach. The length of the intestine is nearly 2 times o~a which winds in the shape of an N. The mucous membrane of the oesophagus consists of longitudinal papillae, while that of the intestine is of zigzag longitudinal folds; wall thin.

The liver not takes so irregular form as those of carp and crusian carp, consisting of 2 lobes. The air-bladder and gall-bladder possess fully the characteristics of those of Cyprinidae.

B. Feeding Habits.

Aside from the examination I made of the stomach contents of this fish, the Gihuken Fisheries Experimental Station had already published a report in

Table 8

Stomach contents of *Tribolodon hakonensis*

			River	Lake Kizaki	Edogawa	Miyagawa	Hisyigawa	Neogawa	Makitagawa	Nagaragawa	Kisogawa	Kasugawa
			Date	Aug. 5, " 10, 1934	June 20, 1933	July 17, 1928	June 15, 1928	June 10, 1928	May 25, 1928	Apr. 18, 1928	Apr. 29, May 2, 1928	Apr. 25, 1928
			Number of fish	8	10	4	10	9	4	3	15	10
			Av. body length (cm)	11.5	19.1	15.9	21.2	20.2	18.1	15.1	19.7	22.5
Stomach contents			♀:♂	3:5	—	1:3	—	5:4	2:2	1:2	—	3:7
			None		1		1					1
			Indistinct	1	2							5
			Sand particles		r	1		28	12		1	
Animal	Fishes		Certain fishes		r. r			1				
			Eggs					4				8
	Arachnoidea		Hydrachnidae			+				3		
			Araneida				1					
	Insecta	Hymenoptera						2				
		Diptera	*Tipula*-larvae					3				
			Culicidae					1				
			Culex								11	
			Chironomus-larvae			11	147				3	
			Adults & larvae	c	c		c. c	8			10	1
		Coleoptera								2		
		Lepidoptera	Larvae				7					
		Trichoptera	*Philoptomus*				9					1
			Molanidae			1						
			Leptocera-larvae					2				
			Limnophilus-larvae			4	12	5		222		
			Adults & larvae									
		Neuroptera					3			+		+
		Odonata		r. r				2				
		Ephemerida	Adults & larvae	r. r		21	4		3			
		Plecoptera				17		5				
			Appendages, etc.	r. r	+		1		1	1	7	
			Eggs	c. c	r		1	1				
			Myriapoda				1	1				
	Crustacea	Arthrostraca	Amphipoda					1	1			
		Phyllopoda	*Bosminopsis*	c. c								
			Cladocera	r	+			9				
		Copepoda	*Limnocalanus*		r							
			Cyclops	c. c								
			Certain copepods	r. r	+							
		Brachyura									1	
		Macrura									2	
	Annelida	Oligochaeta	*Monophylephorus*		c				1			
		Polychaeta	*Nereis ?*		r. r							
Vegetable	Plants		Leaves, roots, etc.	+	+		3		2	18	6	
	Water-Plants		*Zygnema*							+		
			Calothrix		r							
			Spirogyra		+		+	+				
			Bacillariales							+		
			Oscillatoria		+		+					

1928, and so I shall make a review of the results of these studies in table-form, as follows: —

In addition to the foregoing, Yosinaga (1913) stated that the Ugui of the Kagami River, Kôti Prefecture, ate the eggs of the trout, whereas Takayasu and others who obtained their material from Tôfutsu Lake and Akan Lake (1930), reported that the 2 specimens (19 cm in average body length) from the former ate *Mysis* and the 20 fishes (17.5 cm in average body length) from the latter took *Daphnia*, water-mosses and shell-fishes. And further, according to Seiisi (1935), the Ugui found near the Yamaguti Reservoir is known to take pupa or the larvae of Chironomidae and *Leptocerus*. It will be seen from the data given above that this fish is both voracious and omnivorous.

24. *Carassius auratus* (Linné): Huna.

A. Digestive System.

Body oblong, compressed. Head short, compressed. Nostrils 2, very close together. Mouth small (m-c being ca. 1/5, m-b ca. 2/7 of head length), slightly oblique upwards; upper jaw more or less protrusile: lips moderately thick, upper lip being twice as thick as the lower; no barbel. Teeth absent on jaws, vomer, palatines and tongue. Buccal cavity medium size; tongue rather small, triangular, not free, the mucous membrane of which consisting of hooked transversal folds, no melanine chromatophores. Upper and lower pharyngeal teeth well developed, there being 2 rows of the upper, each row consisting of 1 elliptic teeth, and 1 rhombic lower tooth, big and strong. It would seem that both the upper and lower teeth serve their purpose of grinding food very well. Gill-rakers long (the length being ca. 5/4 of corresponding gill-filaments), broad, tips rather pointed, grow thickly, about

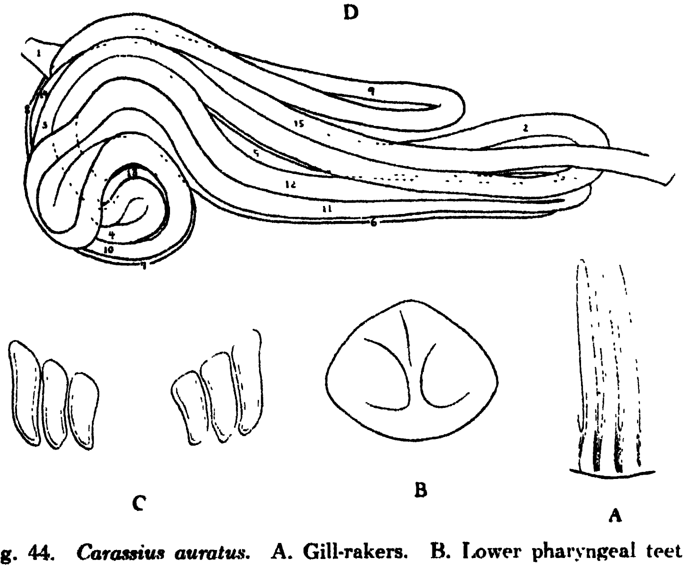


Fig. 44. *Carassius auratus*. A. Gill-rakers. B. Lower pharyngeal teeth. C. Upper pharyngeal teeth. D. Digestive tract.

100 in number, processes on a gill-raker about 25; gill-arch, curving gradually and does not bend.

Peritoneal cavity not large; peritoneum black. Oesophagus and the other parts succeeding it may be distinguished only by the difference of their folds of the mucous membrane, the former consisting of longitudinal parallel folds, while the latter are longitudinal zigzag ones (Pl. IX, Fig. 5), there being no difference between the stomach and the intestine. Intestine extremely long (the length being ca. 11 times of o~a). It must be borne in mind, however, that the length of the intestine of this fish varies considerably, especially in the case of gold fishes which developed from this fish, wall thin. The intestine winds in a very characteristic way, and as illustrated, Nature has so arranged this long intestine so that it may be tucked neatly into the limited peritoneal cavity. It winds back and forth several times and coils up at the front part. No pyloric appendage.

The liver takes the irregular form, fills up the spaces made by the intestinal tract; pancreas not diffuses in the liver. The air-bladder takes after the air-bladder of Cyprinidae, i. e., big and dumb-bell-like. Ductus pneumaticus opening at the end of the oesophagus.

The digestive tract of this fish is described in the text books written by Cuvier and Valenciennes jointly, and Meckel in which they all point out the similarity of this intestine with that of the carp. But I have to say that it is quite different. (Reference " The Digestive System of the Carp ", following this text).

B. Feeding Habits.

This fish is omnivorous and resembles the feeding habits of *Tribolodon hakonensis*, regarding which I have already written. The crucians, 7 to 10 cm in body length, which I had collected in May 1935 at Kasumigaura, Ibaraki Prefecture, had taken, I found, chiefly insect larvae, roots of plants and Crustacea, etc.

25. *Cyprinus carpio* (Linné): Koi.

A. Digestive System.

Body compressed; head medium size; mouth rather small (m-c being ca. 2/11, m-b ca. 1/4 of head length); upper jaw a little shorter than the lower, more or less protrusive; lips rather thick. No teeth on jaws, vomer, palatines, and tongue. 2 pairs of barbels on the upper lip, the front pair being about 4 times as long as the one behind it. Buccal cavity moderately large; folds of palatal mucous membrane at the front part are transverse folds close together, while those at the back are longitudinal folds. Tongue, although medium in size, is covered with a rather thick mucous membrane and consequently cannot be found at a glance. However, the mucous membrane where the tongue is covered rises somewhat and has on it quite large papillary processes. As regards the pharyngeal teeth of the carp (or cyprinoid fishes), they have been studied from times back by many scholars: commencing with the studies of Jurine (1821), Molin (1850), Hoppe (1894), Fack (1899), Gracianov (1900), Cerkasov (1903), Leonhardt (1903), Haempel (1907), Shepherd (1910–

1914), Stoss (1921) and Linden (1921), we have the work of Chu (1935) which is a very complete study of its kind. In p. 158 of his report, he writes: " Pharyngeals rather short and broad, the width about 3 in the length. Anterior limb much shorter than posterior. Pitted surface rather widely expanded, broadly continued in front of the anterior angle to the tip of the anterior limb. Anterior angle triangular, moderately produced, opposite anterior margin of second tooth; posterior angle obsolete. Anterior edentulous process depressed, broad at base and pointed at tip, slightly longer than the dentigerous surface: posterior edentulous process laterally compressed, about

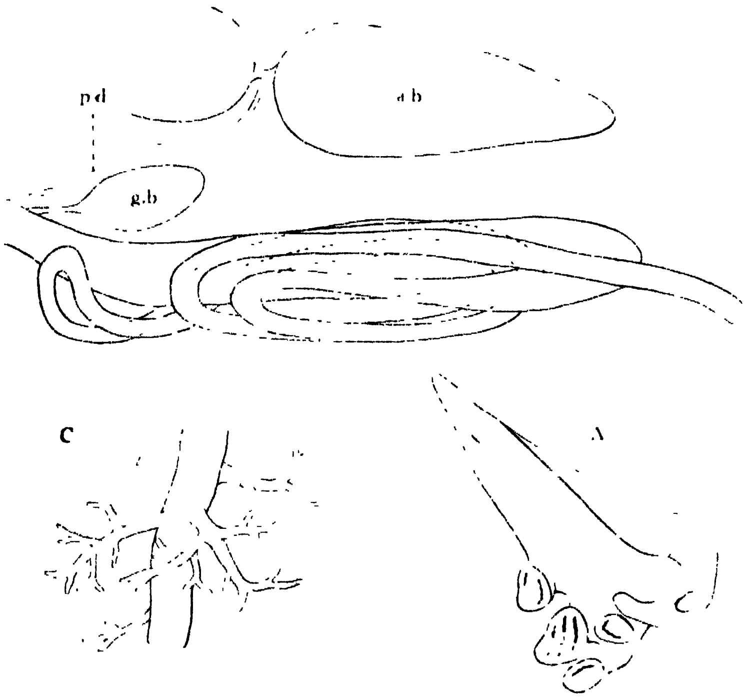


Fig. 45. *Cyprinus carpio.* A. Pharyngeal teeth. B. Digestive system. C. Pancreas.

as long as the dentigerous surface, with the tip obliquely truncate, very slightly twisted outward. Pharyngeal teeth 3-rowed, 1, 1, 3/3, 1, 1, all flattened and molar-like. Excepting the first tooth of the main row, which is an immense crushing molar, smooth on the surface, all other teeth have the surface provided with transverse grooves. A rather prominent body plate behind the last tooth of the main row. A similar but smaller and more rudimentary ridge behind the tooth of each of the outer two rows." Everyone is acquainted with the fact that the pharyngeal teeth are an important index to the classification of Cyprinidae. Gill-rakers coarse, not long (the length being ca. 2/5 of corresponding gill-filaments), tips blunt, about 18 in number. processes on a gill-raker about 15.

Peritoneal cavity rather large, melanin chromatophores scattered in the peritoneum. Oesophagus broad and short, the mucous membrane of which being longitudinal folds. There is no stomach histologically, but there is a broad tube which corresponds to the stomach, the wall of this portion being thick. This curves in the shape of a U and, making 1 turn, connects with a narrow tube which corresponds to the intestine (the part succeeding the oesophagus being, of course, the intestine). The intestine, as illustrated, is much shorter (the length being ca. 4 times o～a) and simpler in the way it winds (there being 5 windings) than that of the crucian, about which I have already discussed. The folds of the mucous membrane are typical double network and differ from those of the previous species (Pl. X, Fig. 12). No pyloric appendage.

Regarding the digestive tract of this fish, there are studies by Cuvier and Valenciennes (1828–1849), Rathke (1820–1825), Šusta (1888), Knauthe (1897), Pictet (1909), Jacobshagen (1911), Okamoto (1917), Sakura (1921) and Klust (1934), who all agree on the absence of a stomach in this fish. Jacobshagen, who made a thorough and detailed study in this connection, said that the intestine of this fish would 5 times as long as the body length, which coincides, I am happy to say, with the results of my studies. There is, however, one point to which I would like to draw my readers' attention, and that is, the scholars who had hitherto engaged themselves in this branch of study, stated that the intestine of the carp and the crucian was very much alike, but, according to my investigations, I am definitely of the opinion that the type of winding, as also the folds of the mucous membrane, of the two intestines are quite different. As for the malformation of the intestine of this fish (there being 2 anuses), there is a study, worthy of note, by Staff (1915).

Liver with the pancreas, takes the form of hepatopancreas. Gall-bladder large, green, bile-duct opening at the beginning of the stomach-like part. Spleen situated on the ventral side of the stomach-like part. Air-bladder almost the same as that of the previous species.

B. Feeding Habits.

Hitherto the carp was thought of as a herbivorous fish, but Šusta (1888) who is known for his study of the carp, found, after careful observation of the stomach contents of this fish, that although this fish fed chiefly on small animals which are found near the banks of lakes or at the bottom and vegetable matter, it also took the plankton, for instance the copepods. Scheffelt and Schweizer (1926) studied the carp of Lake Boden and said that the food of this fish consisted mainly of coastal small animals, shell-fishes and molluscs at the water-bottom, while Contag (1931) said that the food of the carp was chiefly insect larvae and copepods. From the studies of these 3 people, it might be said that this fish was "carnivora akin to omnivora". There is however an interesting statement by Nordgvist (1928), in which he said that this fish took organic matter for its principal food. According to Knauthe (1896–1901), a well known scientist on carp-culture, carps go after food most energetically in a water-temperature of 23–25°C. Supino (1911), Bade (1930) and a few others say that when the temperature drops below 7°C. in winter, it stops taking food.

Family COBITIDAE

26. *Misgurnus anguillicaudatus* (Cantor): Dozyô.

A. Digestive System.

Body elongate, compressed, Snout long, obtuse, rounded and produced; mouth inferior, moderately wide (m-c being ca. 1/16, m-b ca. 1/4 of head length), with thick fleshy lips; of the 10 barbels, 4 are in the lower jaw, the 4 being much shorter than the other 6. Buccal cavity moderate; Plicae palatinae consist of longitudinal folds. Tongue large, not free, rounded, and smooth. No teeth on the jaws, vomer and palatines. Pharyngeal teeth exist but small. Gill-rakers very short, tips pointed, coarse, 13 in number (Pl. IV, Fig. 2).

Peritoneal cavity rather large; peritoneum with melanin chromatophores. Digestive tract runs almost straight from the oesophagus to the anùs. Oesophagus a rather long, narrow tube. The first 1/4 of the digestive tract is the stomach. It is a little thicker than the intestine succeeding it; cylindrical, wall thick; folds of the mucous membrane like the face of a towel (Pl. VI, Fig. 9). The duodenum succeeding it has the thickest wall of the entire intestinal tube and coils up counter-clockwise 2 to 2.5 times. The intestine is a straight, broad tube, with a very thin wall but very elastic; folds of the mucous membrane not well developed, the interior of the intestine therefore being flat (Pl. IX, Fig. 1); blood vessels densely distributed on the surface. Pyloric appendage none whatever.

Okamoto (1917) studied the digestive tract of this fish and said that it had no stomach. Contradicting this statement, Hukuda (1922, 1923), who studied the digestive tract of this fish in detail histologically, not only recognised the existence of its stomach but said that it obtained its nutrition chiefly from the duodenum, while the intestine principally did the work of respiration. The fact that this fish breathes with its intestine, as well as its gills, is a well known fact. In this connection, there are studies by Erman (1808), Edinger (1876), Lorent (1878), Bábak (1907), Bábak and Dedek (1907), Calugareanu (1907), Minobe (1924), Busnitza and Menkes (1931) and Suyehiro (1933).

Liver large, 2 lobes, the right lobe being larger; gall-bladder spherical, rather large, and located in the middle of the right liver. Ductus choledochus opens to the beginning of the duodenum; spleen large, located at the margin of the right liver. First vertebra swells like capsule, and a dumb-bell-shaped air-bladder encloses in it (Fig. 46, D, E).

B. Feeding Habits.

From June 1931 to February 1932, Mr. F. Isikawa, of the Tutiura Branch of the Ibarakiken Fisheries Experimental Station, send me some loaches in formalin solution collected in the paddy-fields of Hirano, not far from the City of Tutiura, once every month, and I examined their stomach contents. As the result of my examination, as shown in the Table 9, I found that the

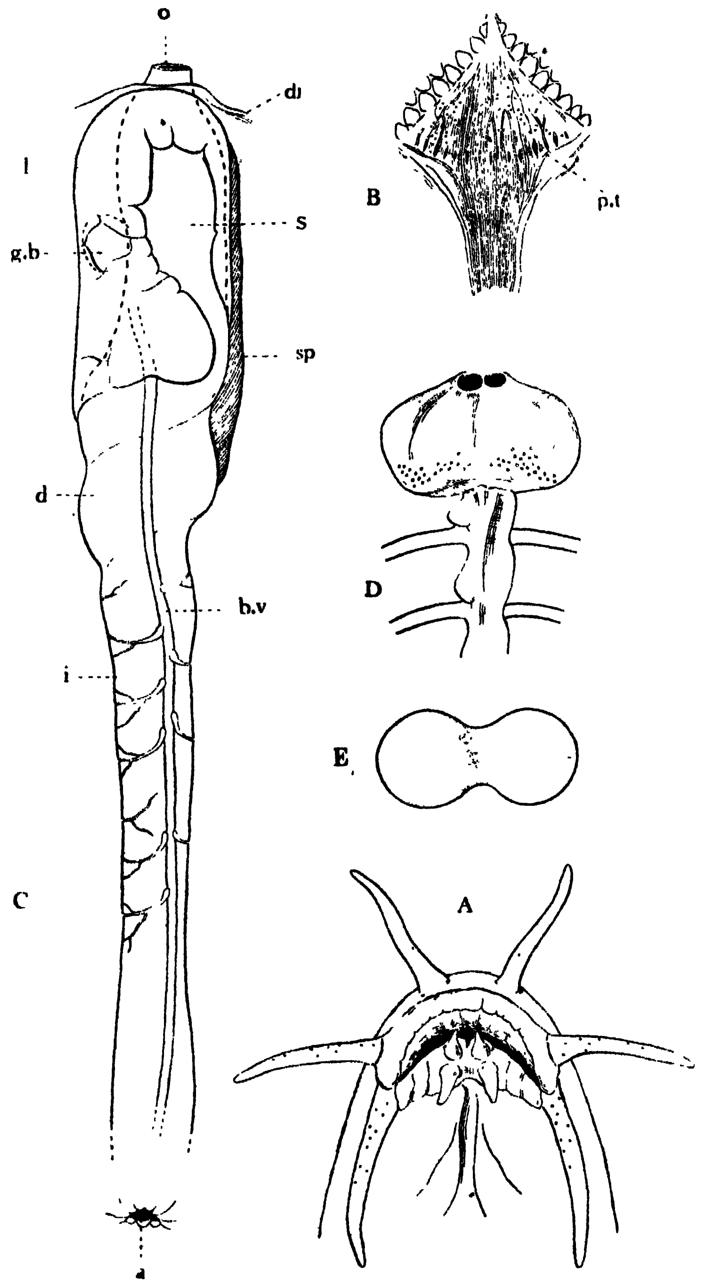


Fig. 46. *Misgurnus anguillicaudatus.* A. Head. B. Pharynx. C. Digestive tract. Ventral side. D. Bony sack of air-bladder. E. Air-bladder.

Table 9

Stomach contents of *Misgurnus anguillicaudatus*

	Date	June 20, 1931	July 20, 1931	Aug. 20, 1931	Sept. 20, 1931	Oct. 20, 1931	Nov. 20, 1931	Dec. 21, 1931	Jan. 21, 1932	Feb. 20, 1932	Frequency
	Locality	„	„	„	„	„	„	„	„	Tutiura, Tiba Pref	
	Number of fish	20	16	12	17	20	20	20	20	20	
	Body length (cm)	6.1~12.3	5.0~9.9	7.9~12.7	7.6~12.4	7.4~12.1	8.5~11.2	8.7~12.2	7.4~10.4	7.2~11.6	
Stomach contents	♂:♀	6:14	5:11	1:11	5:12	15:5	6:14	9:11	5:15	10:10	
Insecta	Larvae of insect	1	3	1	3	1	2	1			12
	„ „ Chironomidae	3	1	1							5
	„ „ Coleoptera	1			1						2
	Kesi-katabiroamembo (*Microvelia douglasi*)				1						1
Amphipoda	*Hyalella* sp.	2				1					3
Copepoda	Certain copepods		1							1	2
	Cyclops sp.	8	6	1						1	16
Phyllopoda	Mizinko (*Daphnia pulex*)	1	1				1				3
	Tama-mizinko (*Moina macrocopa*)	6	3								9
	Hydracarina sp.	1									1
Cyanophyceae	Certain sp.		1		1						2
Mud		1			1	1					3
Indistinct		1	1	1		8					11
None		4	5	9	8	10	17	19	20	18	110

principal food of this was insect larvae, or small Crustacea, taken with mud, and that during the summer season, they had a large appetite and took a large quantity of food, whereas from autumn to winter, they did not eat so much. The digestive tracts of those I had examined were not, in the majority of cases, overstuffed, nor were the intestines particularly stuffed with food. This, I believe, was due to the peculiar habits of this fish, that is, it connects with the intestinal respiration of this fish. I myself do not think that this is a very voracious fish, but in the newspaper article by Araki (1925), who wrote on the aquatic culture of loaches, the pamphlet (1929) issued by the Agricultural Department of Nagano Prefecture and the book of Bade (1930) it is so stated.

27. *Cobitis biwae* (Jordan et Snyder): Simadozyô.

A. Digestive System.

This species is much smaller in size and the body more compressed than the previous species. There is, however, not much difference in the digestive system, except that the present species has 6 barbels (all long) while the previous species has 10, and that the duodenum of the latter made 2 coils whereas the former neither coiled nor wound.

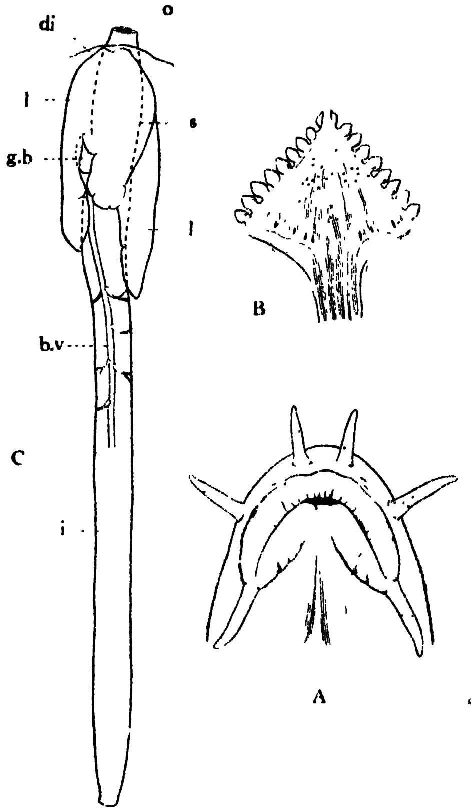


Fig. 47. *Cobitis biwae*. A. Head. B. Pharyngeal teeth. C. Digestive tract.

The liver, especially the left lobe, is a little larger than the previous species. The rest being almost the same as previous species, I shall not go into details.

B. Feeding Habits.

As the present species is found in cleaner bottoms where there are sand and mud and more running water than the foregoing species, which has its habitat in muddy bottoms where the water is very shallow and dirty, the 2 species differ somewhat in their feeding habits. However, from my examination of those collected on June 20, 1931 and February 20, 1932, I found that there was little difference in the food which they took although perhaps the present species had taken more *Cyclops* than the previous species.

Family ANGUILIDAE

28. *Anguilla japonica* (Temminck et Schlegel) : Unagi.

A. Digestive System.

Body elongate, compressed behind. Head long, conical, moderately pointed. Mouth cleft large (m-c being 1/4, m-b ca. 5/16 of head length); lips rather full, with a free margin behind, attached by a frenum in front; lower jaw longer than the upper. Teeth in jaws small, hinged, subequal, conical, in 3 or 4 rows. Mouth cavity moderately large; folds of the palatal mucous membrane longitudinal; vomer armed with a long patch of small teeth. Pharyngeal teeth very minute. No gill-rakers whatever.

Peritoneal cavity slender, the transection of which almost a circle; a distribution of melanin chromatophores on the peritoneum. Oesophagus rather long and narrow, pinkish, wall thick, mucous membrane of the anterior part longitudinal folds, the posterior part changing to small papillae. Stomach Y-shape, peculiar to Apodes; blind sac, long, stretches along the intestine, wall rather thick; the length of the blind sac, the cardiac part and the pyloric part being in the order given. Mucous membrane of the cardiac part consists of about 10 parallel longitudinal folds; the blind sac of transversal folds in addition to longitudinal folds (Pl. VII, Fig. 12); and the pyloric part of longitudinal zigzag folds (about 8). Intestine, almost a straight line, consists of a rather thick duodenum, a middle intestine and a rectum. The posterior part of the middle intestine has an inclination to make short turns as shown in Fig. 48, B (the turns being less distinct in the case of Congridae and other fishes that belong to Apodes). The middle intestine is separated from the rectum by a valve inside. Wall of intestine thick; mucous membrane of the rectum practically even, the remainder of the intestine being net-work as shown in Pl. XI, Fig. 17. No pyloric appendage.

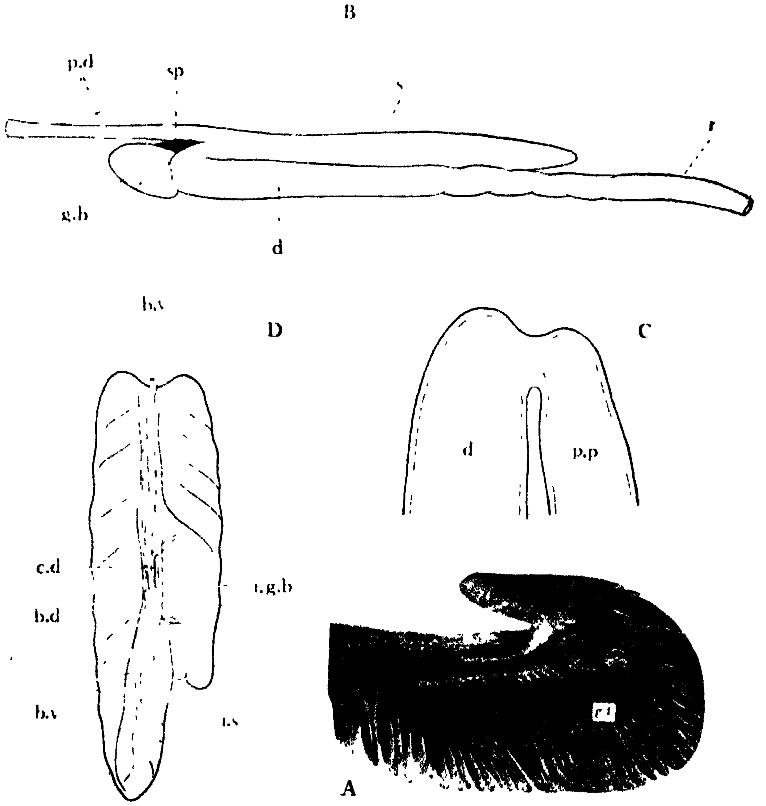


Fig. 48. *Anguilla japonica.* A. Gill. B. Digestive tract. C. Boundary between stomach and intestine. D. Liver.

Liver rather large, very thick, 2 lobes, the left lobe being large and the right small. Impressions of the oesophagus and gall-bladder distinct. Gall-bladder very large, almost spherical, close to the duodenum; bile and cystic ducts both being very short. Pancreas distributed between the stomach and intestine and other places, yellowish, and may be distinguished macroscopically from fat. Islets of Langerhans not isolated. Spleen located at the crotch of the Y-shape stomach. Air-bladder spindle-form, wall thin. Ductus pneumaticus rather long, opens to the oesophagus.

Rudolphi (1802) and Cuvier (1809) have already made a report on the digestive tract of *Anguilla*. Jacobshagen (1911) spent much time, studying it in detail. However, as these studies were conducted on foreign eels, I shall not go into the details of their report. Sakura (1920, 1928) wrote a detailed and excellent report on Japanese eels. He made a macroscopic and microscopic study of their organs.

B. Feeding Habits.

Higurasi (1914) says that natural eels feed on small fishes, shrimps, shell-fishes, etc. According to Marukawa (1915) who made a thorough study of eel-food, this fish will eat anything if of animal matter: hence fishes, insect larvae, shell-fishes, worms, etc., etc. It eats principally at night and will not take food unless the water is above 14°C. It will not eat either if it is too warm.

Family CONGRIDAE

29. *Astroconger myriaster* (Brevoort): Maanago.

A. Digestive System.

Body elongate, formed as in *Anguilla*. Head depressed above, anteriorly pointed. Mouth wide, its cleft extending to below the middle of eye; lower jaw included. Teeth in each jaw small, 2 rowed at sides, those of outer row somewhat larger, subequal, close-set, but without larger canines. Mouth cavity large and horizontal; teeth on vomer small, similar in form to those of jaws, in short band; tongue moderately large, thin, elliptic, free anteriorly, smooth, no melanin chromatophore (Pl. III, Fig. 11). Gill-rakers exist almost rudimentary. No pharyngeal teeth.

Peritoneal cavity elongate; peritoneum racks melanin chromatophore. Oesophagus rather short, wall thick, the mucous membrane consists of longitudinal folds. Stomach large and elongate, Y-shape; cardiac part elongate, blind sac more elongate and the tip rather pointed, pyloric part very short, somewhat oval; wall of stomach rather thick, the mucous membrane consists of longitudinal serpentine folds.

Intestine short (the length being about 1.2 times d~a), runs almost straight, but the posterior part shows characteristic short turnings. (Jacobshagen (1911) observes the similar fact in the case of *Conger conger*); the wall rather thick, the mucous membrane consisting of small papillae and making its appearance the face of a towel (Pl. XI, Fig. 21). Intestine divided in 2 parts, viz. middle intestine and rectum, by a valve between them. Middle intestine closely adhering to blind sac by thick mesentery. No pyloric appendage.

Liver moderate, consisting of a long right lobe and a short left lobe, overhanging and covering the cardiac part of stomach. Gall-bladder rather large and spherical, located at the beginning part of duodenum; bile duct very short, while cystic duct rather long.

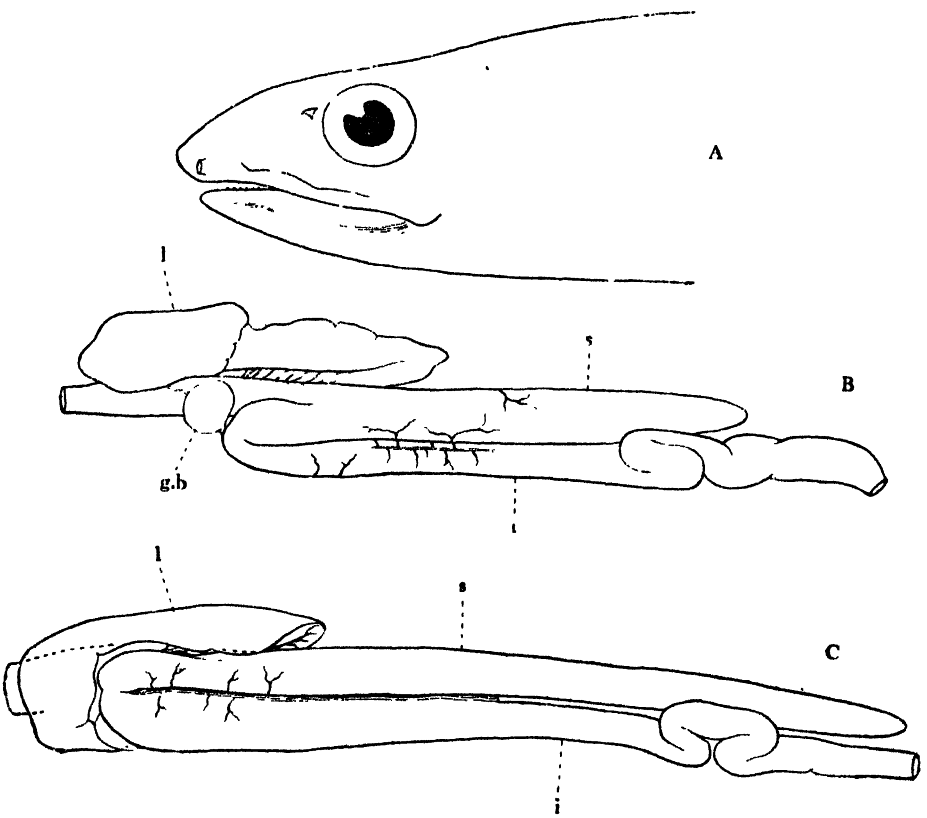


Fig. 49. *Astroconger myriaster.* A. Head. B. Digestive tract. C. Digestive tract of *Alloconger anagoides.*

B. Feeding Habits.

Fortunately, through the kindnesses of Mr. K. Kurata, the proprieter of " Susi-Ei " a noted " Susi " shop on the Ginza, and others, I could obtained a large number of stomachs.

The analysis of the stomach contents showed, as follows, that this fish was carnivorous (viz. it took mainly the larval fishes, the shrimps and the crabs) and exceedingly voracious. It is said that this fish usually takes its food at night.

30. ***Alloconger anagoides*** (Bleeker) : Hana-anago.

There is hardly any difference between the digestive systems of the above mentioned species and the present species saving the slight difference of the turning of intestine.

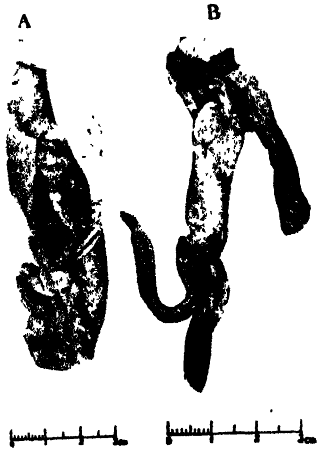


Fig. 50. Food of *Astroconger myriaster.* A. *Sebastodes* in the stomach. B. *Enedrias* in the stomach.

Table 10

Stomach contents of *Astroconger myriaster*

Date	Aug. 17, 1939	June 30, 1936	Mar. 23, 1936	May 20, 1934	Frequency
Locality	Horie, Ehime Pref.	Ogôri, Yamaguti Pref	Onomiti Fish Market	Tokyo Fish Market	
Number of fish	3	25	2	24	
Stomach contents / Body length (cm)	31～33	27～44	30, 34	—	
Certain fishes		4	1	3	8
Madai (*Pagrosomus major*)	2	5			7
Umitanago (*Ditrema temmincki*)		1		2	3
Tenzikudai (*Apogon lineatus*)		2			2
Sebastichthys		2			2
Ikanago (*Ammodytes personatus*)				2	2
Nezuppo (*Callionymus lunatus*)				1	1
Gobiidae		1	1	4	6
Congers				3	3
Certain shrimps	2	9	1	6	18
Akaebi (*Penaeopsis akayebi*)	1	2			3
Saruebi (*Trachypenaeus curvirostris*)				1	1
Certain crabs	1				1
Pinnotheridae				3	3
Leucosia sp.		1			1
Kaimengani (*Acanthophrys longispinus*)	1				1
Cuttle-fishes		2			2
Octopus		1			1
Indistinct				2	2
None		2		1	3

Family MURAENESOCIDAE

31. *Muraenesox cinereus* (Forskål): Hamo.

A. Digestive System.

Body robust. Snout long, rather pointed. Mouth large (m-c being ca. 1/2, m-b ca. 1/6 of head length); upper jaw a little longer than the lower; vomerine teeth large and compressed, tricuspid, 1-rowed; teeth in the inner series of mandible similar to those on the vomer, but smaller and rarely with basal lobes; teeth of the outer series rudimentary, not bent outward. Tongue small, triangular, rather long, not free, no melanin chromatophore. Pharyngeal teeth rudimentary. Gill-rakers absent, but gill-filaments long.

Peritoneal cavity elongate; oesophagus short and rather wide, the folds of its mucous membrane longitudinal. The form of stomach, the folds of its mucous membrane, etc. are similar to those of conger. The length of intestine, the short turnings of its posterior part, the folds of its mucous membrane are also similar. Rectum present, but no pyloric appendage.

Liver not elongate, rather small; gall-bladder spherical; bile duct short. Air-bladder long and fusiform.

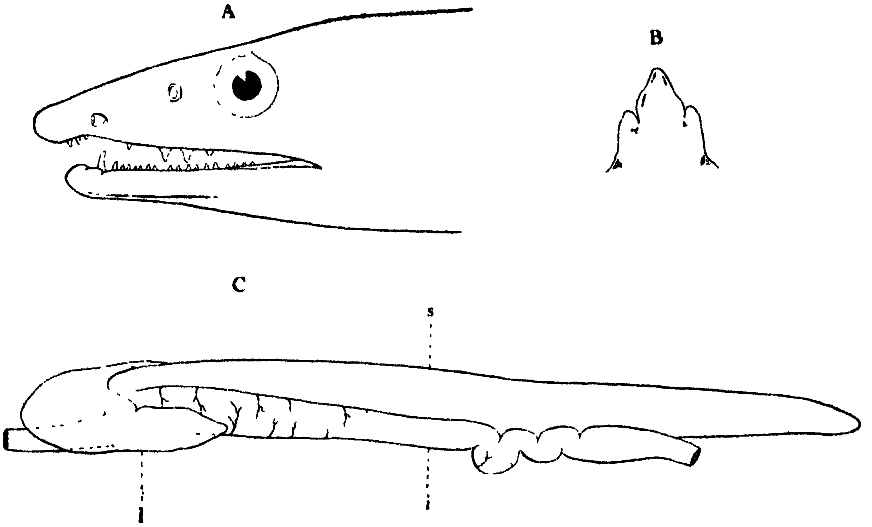


Fig. 51. *Muraenesox cinereus.* A. Head. B. Pharyngeal tooth. C. Digestive tract.

B. Feeding Habits.

I examined the stomach contents of 6 fishes (Body length: 46.2–91.8 cm, Body weight: 125–1420 g) which were collected by the "Utaseami" from the adjacent waters of Ogôri, Yamaguti Pref. on June, 1936, and found that they had eaten voraciously the fishes such as the Kurakakegisu (*Neopercis sexfasciata*), the shrimps and the crabs inhabited on the bottom of the sea.

Family NEMICHTHYIDAE

32. *Nemichthys scolopaceus* (Richardson): Turuunagi.

A. Digestive System.

This fish is one of the rare deep-sea fishes, and although there is a brief description of the external characters of this fish and a few records of collection by such men as Adams (1863, p. 8527–8528), Jordan and Gilbert (1880, p. 409–410), Goode and Bean (1895, p. 153), and Jordan and Evermann (1896, p. 369), no other literature may be had, there being, of course, no one who had made a study of the digestive system of this fish. As reported in my report of 1934 (p. 228–231), I was able to obtain on March 3, 1933, a specimen of this fish (weighing 7.5 g; the length measuring 78.8 cm;

body height 0.8 cm; and body breath 0.4 cm) on the beach of Odawara, Kanagawa Prefecture, which had lost its way. I observed, with great interest and curiosity, the construction of the digestive system and the stomach contents of this specimen. The body was very narrow and long. The jaws were also very long, the upper jaw being trifly longer than the lower (the upper 5.5 cm and the latter 5.3 cm) Viliform teeth (the longest tooth being 0.8 mm) were closely set in the jaws. Buccal cavity not large; tongue long (1.8 cm), triangular, stretching towards the groove of the lower jaw, thin, surface smooth. Gill-rakers and pharyngeal teeth could not be detected.

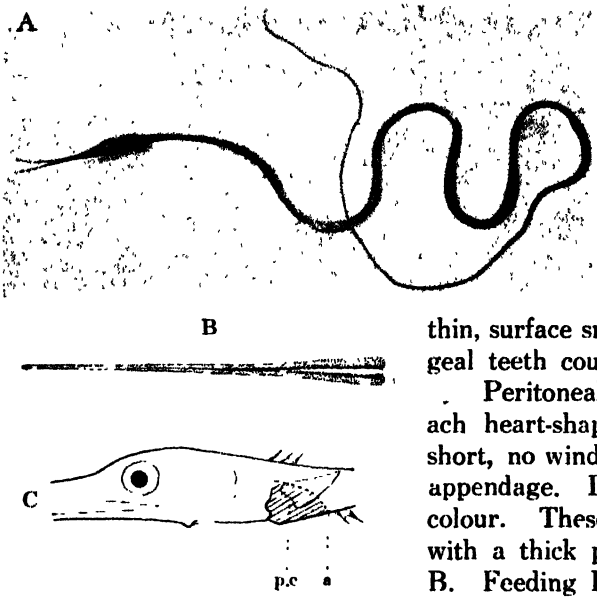


Fig. 52. *Nemichthys scolopaceus.* A. Total view of body. B. Lower jaw. C. Peritoneal cavity.

Peritoneal cavity unusually small; stomach heart-shape, wall thick. Intestine very short, no winding whatsoever, and no pyloric appendage. Liver large and thick, brown colour. These inner organs are covered with a thick peritoneum.

B. Feeding Habits.

What could the usual food of this fish be? — this fish with an unusually long body, with tremendous long jaws that would presumably be in the way for taking food, and with ever so small a digestive tract. However, I could not so much as obtain a hint from my examination, as the stomach of this fish was entirely empty.

Family MURAENIDAE

33. *Gymnothorax kidako* (Temminck et Schlegel): Utubo.

A. Digestive System.

Body much elongate, compressed; head long and snout pointed; mouth large (m-c being ca. 3/7 of head length), completely closed; lower jaw included; teeth rather broad, sharp and pointed, all in single series, without basal lobes; mandible with about 16 teeth on either side. Mouth cavity moderately large; folds of palatal mucous membrane longitudinal; vomer with 1 row of hinged teeth. Regarding to the teeth of *Muraena*, Terra (1911) stated in his book p. 208 as follows: Die Gattung *Muraena* hat pfriemartige scharfspitzige Zähne, die in ein bis zwei, seltener in mehr Reihen stehen. Tongue, pharyngeal teeth, and gill-raker all absent.

Peritoneal cavity elongate; peritoneum grey; oesophngus narrow and rather long, the wall thick, the mucous membrane with 15–16 of longitudinal folds. Stomach assumes the shape peculiar to Apodes, the wall thick, the mucous membrane consists of longitudinal folds and net-work ones. Intestine short (the length being ca. 1.2 times d~a), the posterior part of it makes peculiar turnings as shown in the figure. I think, it is perhaps his mistake in observation that Eggeling (1908) reported taking *Muraena helena* for the material that its intestine made no winding. The wall thick, the mucous membrane consists of net-work folds (Pl. X, Fig. 13). Mesentery thick. No pyloric appendage.

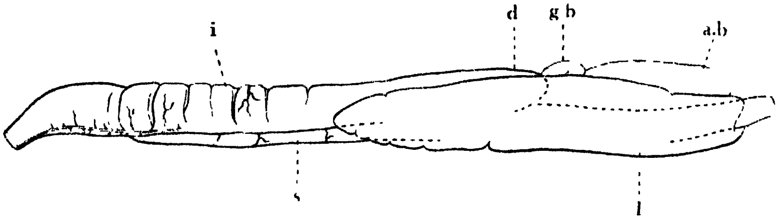


Fig. 53. *Gymnothorax kidako.*

Liver rather large, slender, consisting of 2 lobes, located at the right side of stomach; gall-bladder rather small, spherical; bile duct short. Air bladder small, ellipsoid, the wall thick.

B. Feeding habits.

I examined the stomach contents of 5 fishes (710 g, 69 cm; 455 g, 60 cm; 425 g, 54 cm; 300 g, 51 cm; 124 g, 43 cm) which were collected on July 24th, 1937, from the adjacent waters of the Misaki Marine Biological Station. The results of analysis showed that they had eaten the young fishes, the octopuses, the hermit crabs, etc.

Family FISTULARIIDAE

34. *Fistularia petimba* (Lacépède): Akayagara.

A. Digestive System.

Body very elongate; snout greatly produced, being very long and flute-like; jaws very short and the mouth opening extremely small, the lower jaw being a little longer than the upper. About 24 small conical teeth, almost in a row, curving toward the throat, adorn both the upper and lower jaws. Mouth cavity very elongate, it being possible to broaden or narrow the snout; tongue extremely long and not altogether free, there being some melanin chromatophores on the surface (Pl. III, Fig. 9). No pharyngeal teeth, nor any gill-raker.

Peritoneal cavity elongate; oesophagus rather long, wall thick. The stomach and the intestine run almost in a straight line, the first 1/3 of the alimentary canal being the stomach and the remaining 2/3 the intestine. There is distinctly an outward difference between the stomach and the intestine and in their respective mucous membranes, the former consisting of 8–9 distinct longitudinal folds, while the latter of distinct zigzag folds with a valve separating the two. The end of the intestine is the rectum, separated by a valve. The anus opens just in front of the anal fin; only 1 short pyloric appendage.

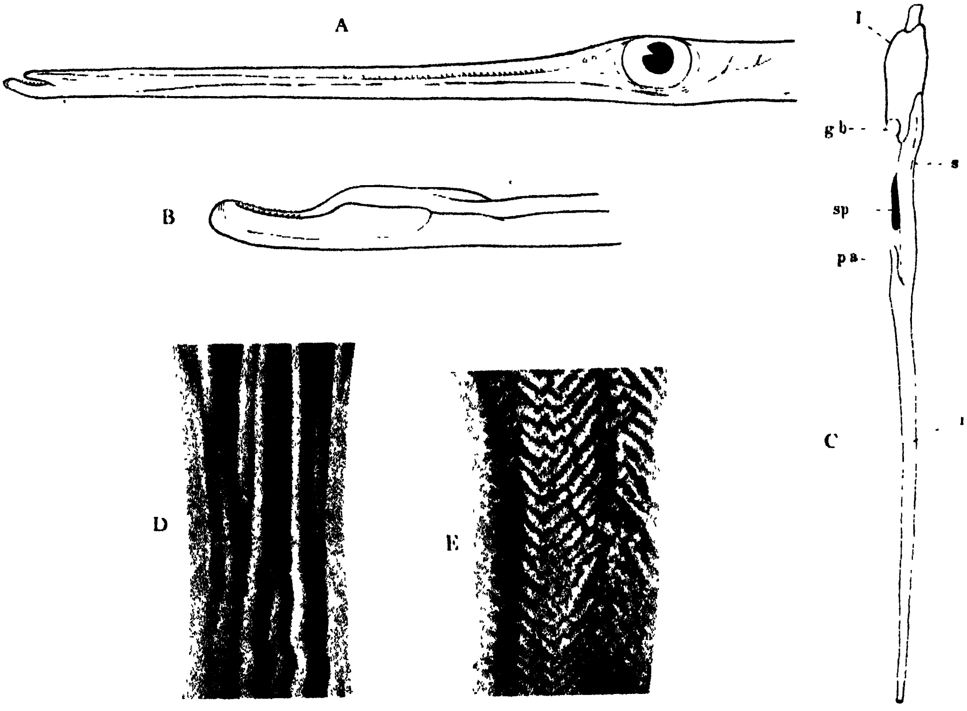


Fig. 54. *Fistularia petimba.* A. Head. B. Lower jaw. C. Digestive tract. D. Folds of mucous membrane of stomach. E. The same of intestine.

Liver small, thin, 1 lobe, located below the anterior part of the stomach; gall-bladder medium in size may be discerned just behind the liver on account of the short bile and cystic ducts. Mesogastrium well developed, holding the stomach firmly in the peritoneal cavity.

B. Feeding Habits.

It is already a well known fact that this fish takes its food, minute floating creatures, by broadening and narrowing its flute-like snout, in other words, by utilizing its snout as a pipette. (See p. 753 of Marukawa's (1931) book).

Family SYNGNATHIDAE

35. *Syngnathus schlegeli* (Kaup): Yôziuwo.

A. Digestive System.

Body elongate, slender, covered with bony plates which are firmly connected, forming a bony carapace. Head slender; snout long and pipette-like, there being short toothless jaws at the end. Mouth cavity narrow; teeth, tongue, pharyngeal teeth, and gill-raker all being absent. Different from those of other fishes, the gill-filaments of this fish are a bunch of clusters, which is worthy to note.

Peritoneal cavity narrow; melanin chromatophores being strewn rather abundantly on the peritoneum. No stomach, so to speak. The alimentary canal consists of a narrow intestine and a broader one succeeding the former. The end of the intestine is the rectum, this part being trifly narrower than the intestine. Mucous membranes of the 2 parts of the intestine are that the former is of broad parallel longitudinal folds whereas the latter is of longitudinal serpentine folds. There is a valve between the intestine and the rectum, there being no material difference in the folds of the mucous membrane of the rectum and the intestine. No pyloric appendage.

Liver small and rather long, consisting of 2 lobes, located below the narrow part of the intestine. Gall-bladder small, ellipsoidal; bile and cystic ducts both short. Air-bladder large and long, being almost the same length as the intestine. The pneumatic duct opens at the beginning part of the intestine.

There are no report whatsoever on the digestive tract of this fish. There are, however, studies by Cuvier (1910), Rathke (1837), Pilliet (1894) etc. on the digestive tract of *Syngnathus acus*, but as this species is almost the same as the present species, I shall omit describing them.

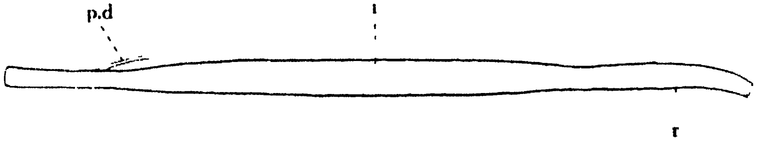


Fig. 55. *Syngnathus schlegeli.*

B. Feeding Habits.

Syngnathus uses its pipette-like snout as a pipette to obtain minute creatures in the water, and, as stated, scholars like Gill (1905) and Rauther (1925) agree insofar as this statement is concerned. Bigelow and Welsh (1925) however, describes that the snout of *Siphostoma fuscum* is so distensible that it can swallow larger prey than one might expect.

36. *Hippocampus coronatus* (Temminck et Schlegel): Tatuno'otosigo.

A. Digestive System.

As everybody no doubt knows, this fish has a very peculiar form, a very compressed body. Snout slender, about as long as the postorbital part of the head; mouth extremely small (m-c and m-b both being ca. 1/20 of head length). The mouth viewed directly from the front is a half-moon. Devoid of all teeth, tongue, pharyngeal teeth and gill-raker. The gill-filaments assume a very characteristic form, a bunch of clusters, the same as in the previous case. They make one think of the cockscomb.

Peritoneal cavity vertically long and compressed sidewise, on account of which the long alimentary canal, that is, the intestine (this fish being devoid of a stomach, the alimentary canal just about corresponds to the intestine), is unable to wind from left to right and winds vertically up and down several times. Succeeding the pharynx, the oesophagus first runs horizontally but it immediately changes its course and bends down. The intestine succeeds the oesophagus, it being a trifle narrower, and the total length of which is approximately 2.5 times o~a (there being quite a difference with each individual fish); wall rather thin; the mucous membrane of the oesophagus consisting of longitudinal folds and that of the intestine of papillary processes. The end of the intestine, the part which suddenly swells up, is the rectum. No pyloric appendage.

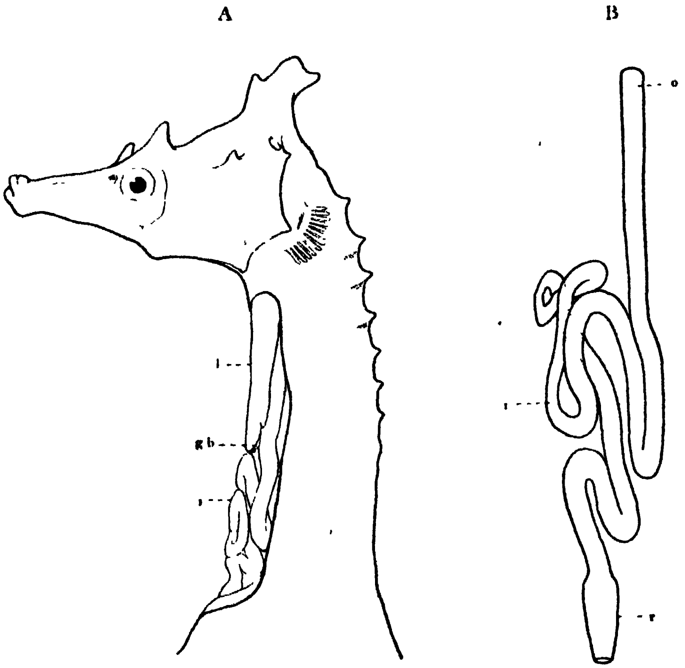


Fig. 56. *Hippocampus coronatus*. A. Head and abdomen. B. Digestive tract.

Liver rather long, located on the left side of the beginning of the intestine and consists of 1 lobe which gives the impression of being subdivided in 2. Gall-bladder small and ellipsoidal, located to the left of the liver, right behind the lower part (bile and cystic ducts both being short). Pernkopf (1930) rendered a concise report on the digestive tract of *Hippocampus*.

B. Feeding Habits.

According to Gill (1905), Rauther (1925) and Marukawa (1931), it would seem that the food and the manner in which this fish obtained its food were almost the same as the species described above.

Family BELONIDAE

37. *Athlennes anastomella* (Cuvier et Valenciennes) : Datu.

A. Digestive System.

I examined 1 sample only, as follows : —
Date of collection : June 26, 1937 ; locality : off the coast of Hunabasi, Tiba Prefecture (Depth : about 4 ft, sandy bottom) ; collector : Mr. S. Miyauti ; body length : 70 cm ; head length : 19 cm ; lower jaw : 11 cm ; upper jaw : 10.2 cm ; o~a : 11 cm ; intestine : 11.2 cm.

Body very elongate, slightly compressed. Jaws very long (the lower being longer than the upper), narrowing as they get toward the tips. As stated, the jaws are extremely long and the mouth correspondingly very large (m-c being ca. 5/9 of head length). 5 rows of rather large conical teeth arm the jaws, the teeth of the innermost row, about 30 of them, are especially large, the rest being much smaller in comparison. No teeth on the vomer and palatines. Tongue very long, runs parallel with the groove in the middle of the lower jaw, not free, melanin chromatophores diffused on the surface. Pharyngeal teeth not very large but sharp, curving trifly in.

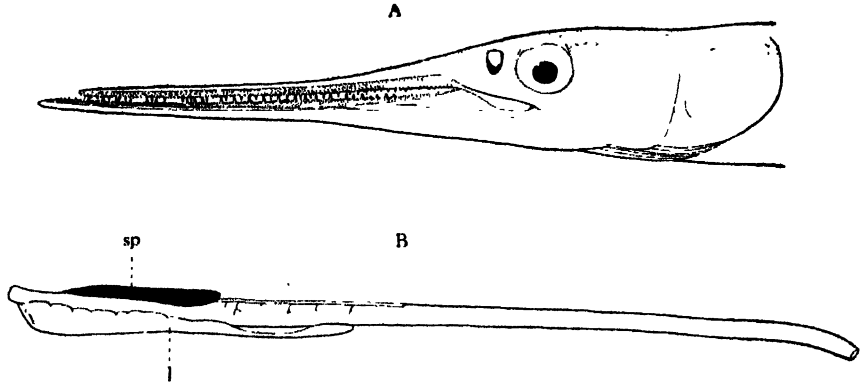


Fig. 57. *Athlennes anastomella.* A. Head. B. Digestive tract.

Peritoneal cavity elongate ; melanin chromatophores abundantly scattered on the peritoneum. Alimentary canal constitutes almost a straight line, broad, wall thick, divided into the oesophagus and the intestine ; the end being the rectum ; no stomach. Mucous membrane of the oesophagus longitudinal folds, while that of the intestine papillary processes close together, the same as that of the flying-fish which will be described later. The intestine is divided by a valve into the middle intestine and the rectum. No pyloric appendage.

Liver elongate, the division of right and left lobes not at all distinct, thick. Gall-bladder spherical ; bile and cystic ducts both extremely short. Air-bladder large, elongate, the first half being particularly broad.

B. Feeding Habits.

The sample fishes which I examined had in their stomach bones which indicated that they were the remains of pretty large fishes. According to the fishermen, this fish seems to make full use of its long jaws and sharp jaw teeth to attack rather large fishes, from which it would indicate that the jaws of this fish are not useless or cumbersome as the jaws of *Hemirhamphus sajori*, about which I shall relate in the following chapter.

Family HEMIRHAMPHIDAE

38. *Hemirhamphus sajori* (Temminck et Schlegel): Sayori.

A. Digestive System.

Body much elongate, slightly compressed. Head moderately large, snout with obliquely directed, straight profile and pointed tip; lower jaw much longer than the upper. Mouth large; teeth in jaws minute, tricuspid, in narrow bands; no teeth in the posterior part of lower jaw, on the vomer and palatines.

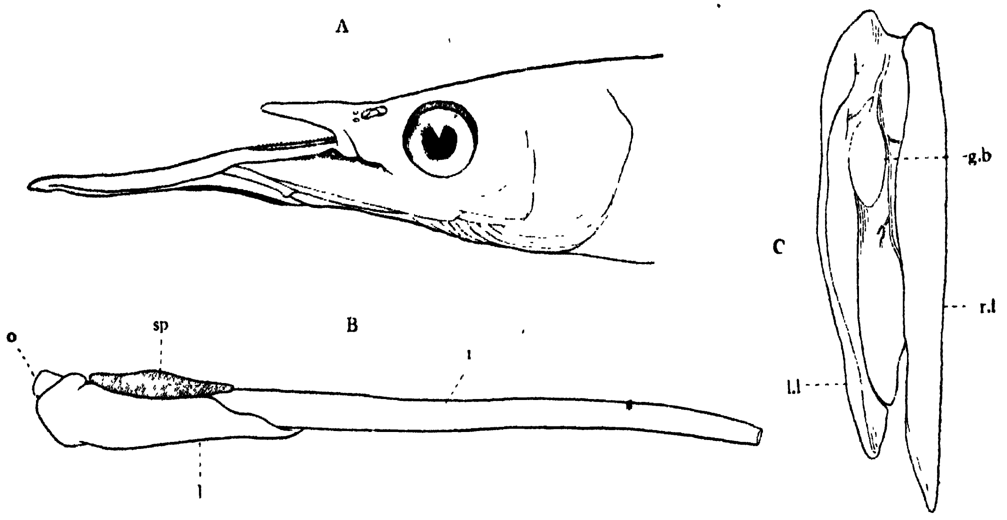


Fig. 58. *Hemirhamphus sajori*. A. Head. B. Digestive tract. C. Liver with gall-bladder.

Tongue rather large, rectangular, long and rather thick, free, no melanin chromatophores. Pharyngeal teeth small but numerous. Gill-rakers rather short (the length being ca. 2/5 of corresponding gill-filaments), tips pointed, grow coarse, 23 in average number.

Peritoneal cavity elongate; peritoneum thin and black. Alimentary canal closely resembles the above-mentioned species: it consists of oesophagus, middle intestine and rectum (no stomach); it runs almost straight from oesophagus to anus; the wall thick; the mucous membrane of intestine consists of numerous small papillae; there is a valve between the middle intestine and the rectum. No pyloric appendage.

Liver slender, consisted of incomplete 2 lobes, located underneath the anterior part of intestine; gall-bladder small and ellipsoidal; bile and cystic ducts short. Air-bladder large and slender.

B. Feeding Habits.

According to the foreign literatures, the fishes of Hemirhamphidae are all vegetable feeders, for instance, Jordan (1907) describes this in his book, p. 428, but from what Uchida (1930) examined, this fish seems to be carnivorous, viz. it takes zooplankton such as small Crustacea. He also ascertained that its long lower jaw was not only useless when taking its food but was rather a hindrance.

Family EXOCOETIDAE

39. *Cypsilurus agoo* (Temminck et Schlegel): Tobiuwo.

I have already made a report (1935) on the digestive system and the feeding habits of this fish.

A. Digestive System.

Body elongate, broad above, somewhat compressed. Head short; mouth vertical, small (m-c being ca. 1/6, m-b ca. 1/4 of head length); lower jaw trifly longer than the upper. Villiform teeth scattered in jaws. No teeth on vomer and palatines. Mouth cavity moderately large: tongue rectangular, medium in size, free anteriorly, smooth, melanin chromatophores scattered on the surface. Pharyngeal teeth characteristic tricuspid, rather large and closely set. Gill-rakers short (the length being ca. 1/2 of corresponding gill-filaments), tips rather pointed, coarse, 22–27 in number (the number seems to decrease with age), process not numerous.

Peritoneal cavity large, elongate: a few melanin chromatophores scattered on the peritoneum. The alimentary canal runs almost straight from the oesophagus to the anus; oesophagus short and narrow; stomach absent histologically (no gastric gland); intestine very wide anteriorly and rather narrow posteriorly; the wide part being the middle intestine and the narrow part the rectum, the length of the former being about 3 times the latter, and there is a valve between the two parts. The mucous membrane of the middle intestine forming rather long and broad papillae, while the rectum short and rather narrow ones. Anus opens just in front of the anal fin. No pyloric appendage. Mesentery not well developed.

Liver, rather small, consisted of 2 lobes, the left lobe being larger than the right; gall-bladder large and ellipsoidal; bile duct and cystic duct short. Spleen moderately large, located near the liver. Air-bladder large and long, pneumatic duct opening to the oesophagus.

As for the digestive tract of this fish, Okamoto (1918), not only made a mistake in taking the middle intestine for the stomach, but said that there was no valve dividing the middle intestine from the rectum.

B. Feeding Habits.

The feeding coefficient of this fish, that is, the value of (food weight ÷ body weight−food weight) × 1000 is not over 17, from which it may be seen

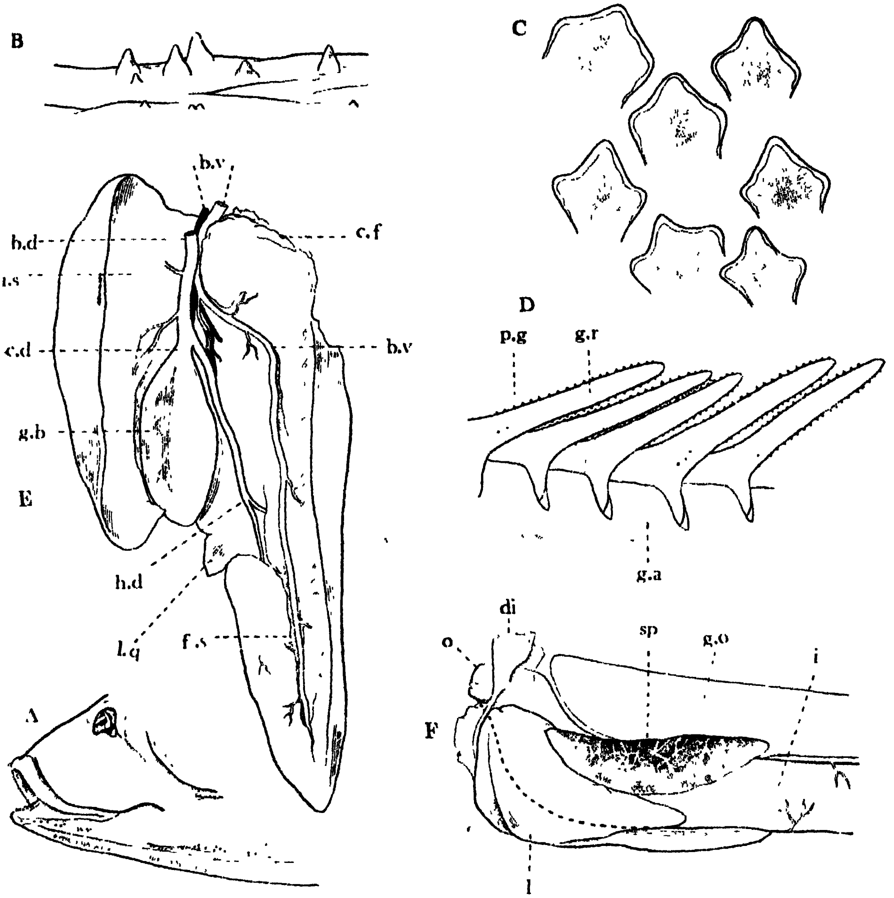


Fig. 59. *Cypsilurus agoo.* A. Head. B. Jaw teeth. C. Pharyngeal teeth. D. Gill-rakers. E. Liver. F. Anterior part of digestive tract.

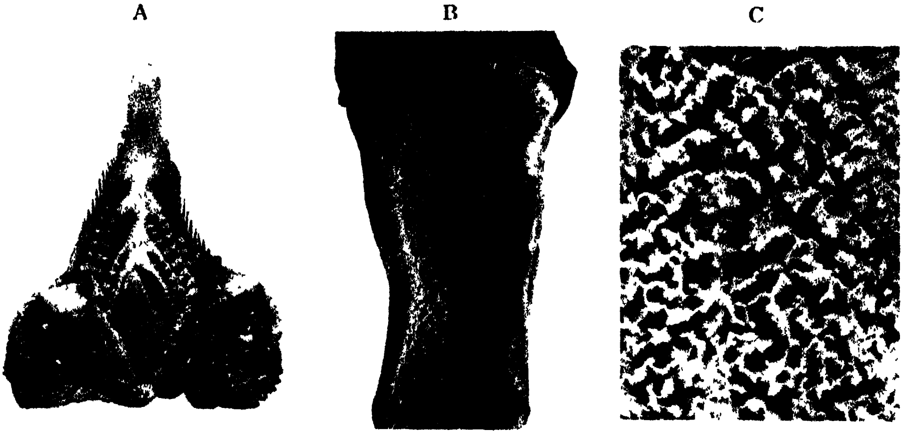


Fig. 60. *Cypsilurus agoo.* A. Gill. B. Folds of mucous membrane of duodenum. C. Folds of mucous membrane of middle intestine.

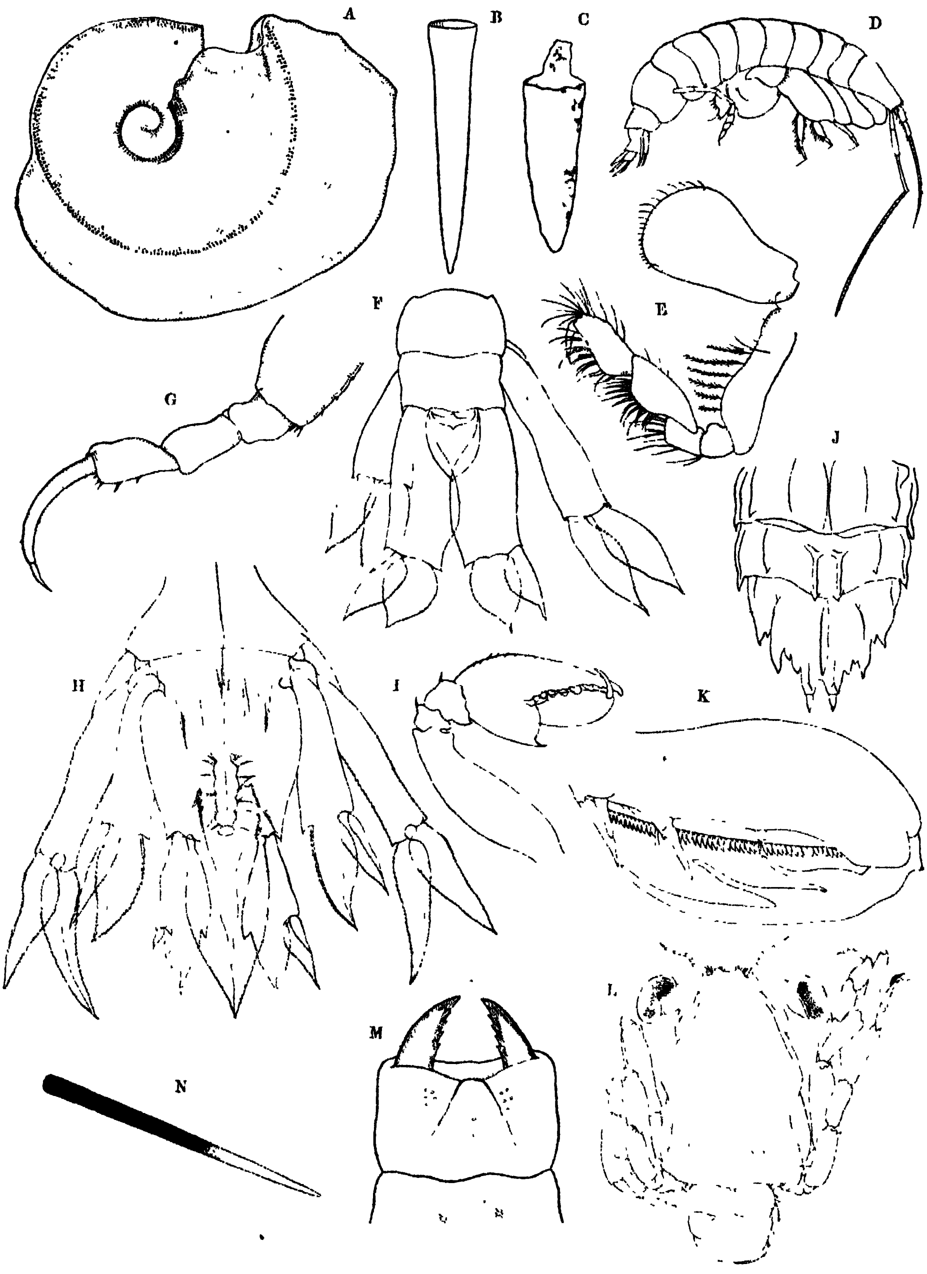


Fig. 61. Stomach contents of *Cypsilurus agoo*. A. *Atlanta peronii*. B. C. *Creseis*. D. *Ampelisca zamboangae*. E. do: gnathopod. F. *Hyperia sibaginis*: telson. G. do: 1st peraeopod. H. *Oxycephalus*: telson. I. do: gnathpod. J. *Pseudosquilla ferussaci*: telson. K. do: dactylus. L. Megalopa larvae of *Oxyrhyncha*. M. *Nereis*: head with jaw. N. do: setae.

that it eats very little. As shown in the table, it takes for its principal food zoo-plankton found in warm currents, or more precisely, planktonic Crustacea, such as Amphipoda and Pteropoda and Polychaeta. A matter of interest in this connection is that a great deal of its own eggs are found among the stomach contents. This, I believe, is due to the large quantity of eggs it produces during its spawning season.

Table 11

Stomach contents of *Cypsilurus agoo*

	Date	May 20, 1929	Oct. 7, 1929	Apr. 21, 1930	May 6, 1930	May 11, 1930	May 15, 1930	June 13, 1930	July 10, 1930	Sep. 11, 1930	Oct. 12, 1930	Oct. 18, 1930	Apr. 30, 1931	May 14, 1931	Frequency
	Locality	Sagami Bay	Sagami Bay	Adjacent waters of Hatizyózima	Off the coast of Siwonomisaki	Koaziro Bay	Off the coast of Kumage	Koaziro Bay	Sagami Bay	Sagami Bay	Off the coast of Siwonomisaki	Sagami Bay	Off the coast of Simoda	Sagami Bay	
	Number of fish	10	10	10	10	10	12	10	10	5	10	5	10	5	
	Av. body weight (g)	295	435	381	408	240	214	200	102	284	353	378	453	415	
	Av. body length (cm)	27.1	34.6	31.9	31.9	24.7	24.3	23.3	19.3	26.5	30.1	30.2	31.9	31.1	
	♀ : ♂	7:3	3:7	0:10	0:10	1:9	2:10	2:8	9:1	1:4	0:10	2:3	2:8	1:4	
	Feeding coeficient / Stomach contents	10	12	12	17	2	6	2	6	2	8	13	7	3	
Gastropoda	*Atlanta peronii*	2						1							3
	Creseis sp. 1	1					2				1		2		6
	Creseis sp. 2										1				1
	Hyalea longirostris										2			1	3
	Certain *Pteropoda*											2	1		3
Crustacea	*Ampelisca zamboangae*		2	1									2		5
	Hyperia sibaginis			2											2
	Hyperia sp.		1						1						2
	Oxycephalus sp. 1	1							1						2
	Oxycephalus sp. 2	6										1			7
	Platyscelus ovoides										1				1
	Phronima pacifica			1											1
	Viblia viator		1												1
	Larvae of *Squilla*										1			1	2
	Pseudosquilla ferussaci												3		3
	Euphausia pellucida		2			1	1								4
	Certain *mysis*							1							1
	Megalopa of *Oxyrhynca*		1	1	9				1				2	2	16
	Certain Ostracoda						1				1				2
Chaetopoda	Larvae of *Mitraria*									1					1
	Larvae of Polychaeta	1	1	2		2	2		2						10
	Nereis sp.			3											6
	Rhynchonerella fulgens					1									1
	Certain Polychaeta		1		2										4
Radiolaria	*Phormocampida* sp.								4						4
	Certain Radiolaria		1	2			2						2		7
	Eggs of *Cypsilurus agoo*		1				6			1				1	9
	None	2	2	3	1	4	2	7	5	2	3	1	2	0	34

40. *Cypsilurus japonicus* (Franz): Hamatobiuwo.

From my observation of a sample of this fish (body length 25.5 cm) which Mr. S. Masuda obtained off the coast of Misaki and gave to me in the summer of 1930, I found that it was almost impossible to tell the difference between the digestive tracts of the present species and the previous one.

As regards the digestive tract of Exocoetidae, Meckel studied it with *Exocoetus exsiliens* and *E. volitans*, while Cuvier and Valenciennes, with *E. volitans*, but from the results of their examination, it would seem that there was not much difference between the digestive tracts of *Cypsilurus agoo* and *C. japonicus*. According to Yarrell (A History of British Fishes, 1836, Vol. I, p. 456), *E. volitans* eats small fishes in addition to Crustacea.

Family SCOMBRESOCIDAE

41. *Cololabis saira* (Brevoort): Sanma.

A. Digestive System.

Body elongate, compressed; head rather large, compressed. Mouth rather small (m-c being ca. 4/17, m-b ca. 2/21 of head length), oblique; lower jaw longer than the upper without forming a long beak; teeth extremely small, in a single row on the edge of the jaws. Mouth cavity small: no teeth on vomer and palatines; folds of the palatal mucous membrane longitudinal.

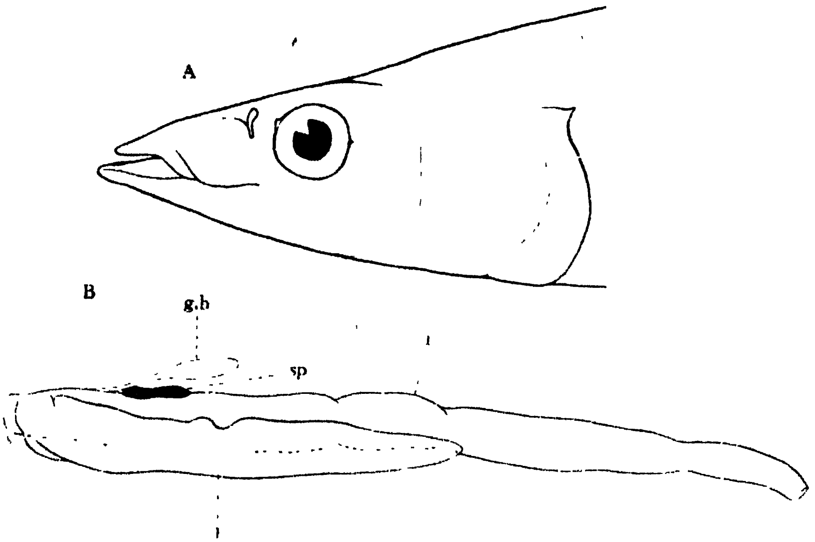


Fig. 62. *Cololabis saira*. A. Head. B. Digestive tract.

Tongue elongated rectangular, rather large, free, flat anteriorly, rich in melanin chromatophores (Pl. III, Fig. 8). Pharyngeal teeth minute, numerous. Gill-rakers long (a little shorter than corresponding gill-filaments), flat, about 50 in number, process on a gill-raker numerous.

Peritoneal cavity rather large and compressed; peritoneum thin and black.

Oesophagus short, wall rather thick, mucous membrane consists of about 20 longitudinal folds. No stomach. Intestinal tract runs almost straight; divided by a valve into 2 parts, viz. middle intestine and rectum. Wall of the intestinal tract easy to self-decomposition, mucous membrane consists of papillary processes (Pl. XI, Fig. 22).

Liver rather large and slender, thick, consisting of 2 lobes, located below the anterior part of the intestine; gall-bladder ellipsoidal; bile duct rather short. Spleen very small. Air-bladder slender, wall thin.

B. Feeding Habits.

In October 1935, off the Coast of Tyôsi, Tiba Prefecture, Mr. M. Sakai made experiments in an effort to ascertain the connection between the size of mesh of a gill-net and the catch of mackerel-pike. He turned over to me all the fish he caught during this experiment. He took these samples and made a study of their size, examining at the same time their stomach contents. As these sample fishes were caught with nets of different-sizes, they were divided into 6 groups, i. e. Group A (23.0 to 30.2 cm); Group B (22.4 to 30 cm); Group C (26.3 to 30.6 cm); Group D (27.5 to 30.8 cm); Group E (28.5 to 31.5 cm); and Group F (28.4 to 31.4 cm), each group consisting of 10, which make in all a total of 60.

The analysis of the stomach contents of these fishes revealed that the plankton was their chief food: they were Diatoms (*Coscinodiscus subtiles, Cos. radiatus, Cos. sp., Navicula monouthiana, Nav. sp., Hyalodiscus sp., Rhizosolenia sp.*, etc.), Polychaeta (*Alciopa, sp., Tomopteris sp.*, Polychaeta larvae), *Tintinnopsis, Creseis*, and Amphipoda, especially planktonic Polychaeta constituted the main portion of the contents. This is very important insofar as the feeding habits of this fish are concerned.

Family TRACHYPTERIDAE

42. *Trachypterus iris* (Walbaum): Tengaihata.

I examined the digestive system and the feeding habits of this species with only 1 specimen (19.7 cm, 8.1 g) which was collected from the adjacent waters of Komegami, Kanagawa Pref. on September 17, 1935.

A. Digestive System.

Body elongate, very much compressed, riband-shaped. Head square; mouth rather small (m-c being a little shorter than 1/5 of head length), slightly upwards. Mouth cavity rather large but compressed; no teeth on the jaws, vomer, palatines and tongue. Tongue rudimentary. Pharyngeal teeth absent. Gill-rakers long (as long as corresponding gill-filaments), slender, tips pointed, grow coarse, 13 in number.

Peritoneal cavity small and compressed. Oesophagus short and broad, wall thick, the mucous membrane consists of about 8 longitudinal folds of papillary processes. Stomach, ⊣-shape, consisting of long cardiac part, long blind sac and short pyloric part; the folds of its mucous membrane are not distinct in my specimen. Duodenum curves U-shape, and intestine runs straight;

the former being about twice as broad as the latter; wall of intestinal tract thin, and the mucous membrane assumes longitudinal zigzag folds. Pyloric appendages short, ca. 200 in number, located on the either side of duodenum as shown in the figure.

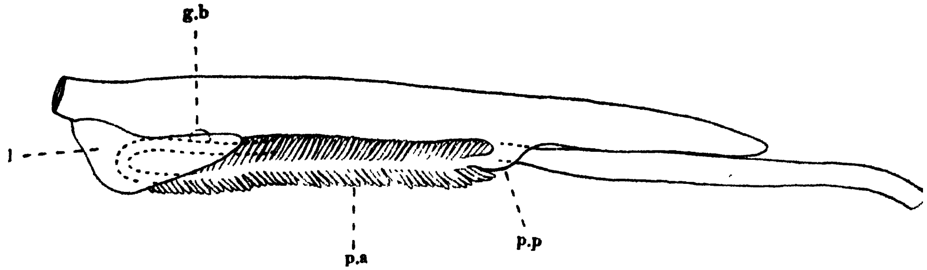


Fig. 63. *Trachypterus iris.*

Liver small, 2 lobes, rather thick, embracing the cardiac part of stomach from below. Gall-bladder small, spherical, located between the cadiac part and duodenum. No air-bladder.

Regarding the digestive tract of the fishes of family Trachypteridae, Cuvier and Valenciennes studied that of *Trachypterus liopterus*, and Mazza (1901) researched taking *Regalecus glesne* and Regan (1907) observed taking *Velifer hyoselopterus* for their materials.

B. Feeding Habits.

The stomach contents of the fish used for my present study consisted of large number of Schizopoda.

Family SPHYRAENIDAE

43. *Sphyraena pinguis* (Günther): Akakamasu.

A. Digestive System.

Body elongate, more or less compressed. Head rather pointed. Mouth rather large (m-c being ca. 2/7, m-b ca. 2/13 of head length); lower jaw longer than the upper. Pointed large canine teeth and minute conical teeth on jaws, vomer and palatines; palatine teeth especially enlarged. Mouth cavity medium in size; tongue elongated rectangular, free, thin, moderately large, very few melanin chramatophores and rudimentary teeth on the surface. Pharyngeal teeth villiform. Gill-rakers degenerated.

Peritoneal cavity elongate; peritoneum silvery. Stomach elongate, ˧-shape, wall thick, mucous membrane consists of about 15 longitudinal serpentine folds; blind sac the longest. Intestine short (almost as long as d$\sim$a), having no winding, narrow, wall thin, mucous membrane with numerous minute papillary processes. Intestine divided by a valve into middle intestine and rectum. Pyloric appendages long and slender, about 25 in number.

Liver rather large, 2 lobes, left lobe slightly longer than the right, rather thick, lifting the stomach and pyloric appendages from below; gall-bladder rather large, ellipsoid, located near duodenum. Spleen small. Air-bladder very long and large, wall thick and silvery.

B. Feeding habits.

According to the fishermen, this fish usually lives near the rocky bottom of the comparatively shallow sea where the algae luxuriant, and feeds mainly on the small crustaceans and young fishes.

Family MUGILIDAE

44. *Mugil cephalus* (Linné): Bora.

A. Digestive System.

Body rather elongate, compressed. Head short, broad, slightly compressed; nostrils at some distance from each other. Mouth subinferior, mederately large (m-c being ca. 2/11 in head length and m-b twice as long as m-c); upper jaw slightly longer than the lower; cleft of mouth assumes Λ-shape; a series of small teeth in both jaws but none on the vomer and palatines. Buccal cavity moderate; Plicae palatinae form longitudinal folds. Tongue fairly large, not free, semi-elliptic, small papillae exist on the surface, no malanin chromatophores. No teeth in the pharynx, instead transversal folds and many soft small processes. Gill-rakers moderately long (the length being ca. 1/2 of corresponding gill-filaments) and slender, tips rather pointed, closely set, about 140 in number.

Peritoneal cavity rather large. Oesophagus moderately long, wall tolerably thick; mucous membrane feathery processes vertically in rows. Stomach not large, neither Y nor V-shape, something between; blind sac rudimentary. Contrary to the cardiac part being small, the pyloric part is big and characteristic in shape, that is, very big in comparison with the other parts of the stomach and assumes the shape of a humming-top, wall thick, similar to a bird's gizzard (Kropfmagen). Folds of the mucous membrane of the cardiac and pyloric parts not clear but those of the blind sac are distinct network. Intestine not narrow but very long (the length varying according to each fish, it averaging however approximately 5 to 6 times the body length, or 10 to 11 times d∼a). As illustrated, it winds back and forth several times, presenting a very intricate type of winding. The winding at the middle part of intestine is most variable according to each fish. Folds of the mucous membrane short papillae irregularly arranged, somewhat like the surface of a towel (Pl. XII, Fig. 26). Pyloric appendages succeed the pyloric part, moderately long, rather thick, 2 in number (6 in the case of *Liza haematochila*).

As this is a well-known fish throughout the world, the digestive tract of which has been studied by scholars of every country. First, we have Cuvier and Valenciennes who in their "Histoire naturelle des poissons", Vol. II, dealt with the form of its digestive system in general. It was they who said that the stomach was similar to a bird's gizzard, and reported that the intestine was long and made of about 20 winding. Rathke (1824) also wrote about the peculiarity of its stomach and intestine. Haller (1904) not only took up the peculiarity of the stomach but said that it had a close connection with its feeding habits. Jacobshagen (1911) studied in detail the folds of the

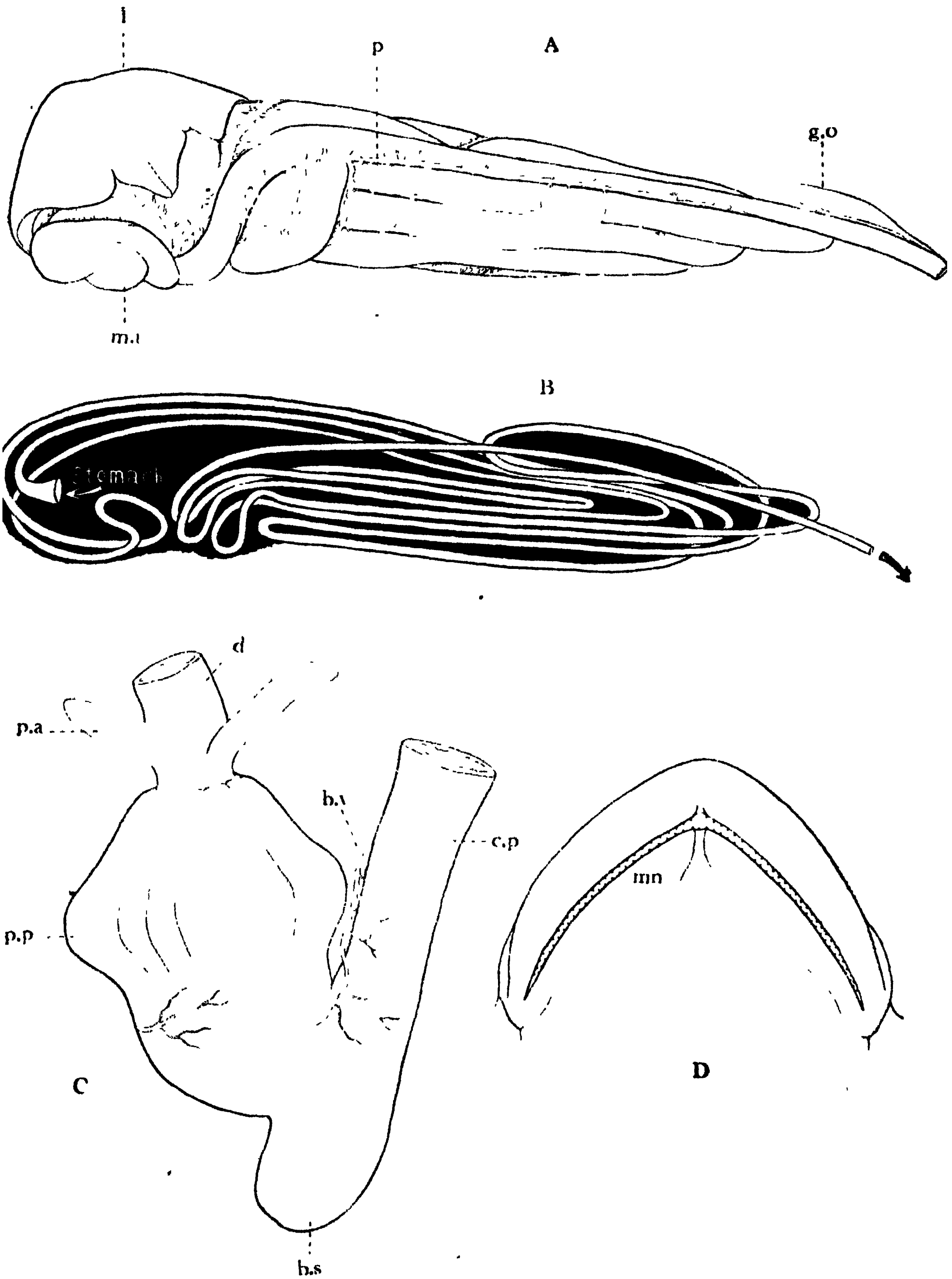


Fig. 64. ***Mugil cephalus.*** **A. Digestive tract. B. Diagram showing the intestinal winding-type. C. Stomach. D. Cleft of mouth.**

Table 12
Stomach contents of Mugilidae (After Ghazzawi)

	Sample	*Mugil cephalus*																				*Mugil capito*																														
	Body length (cm)	26	27	27	28	29	29	29	30	31	27	28	28	28	29	29	29.5	30	30	30	30.5	20	20	21	21	22	22	22	22	23	23	23	23.5	24	20	20	20	20	21	22	22	22	22	22	22	22	23	23	24	20	21	22
	Sex	♂	♂	♂	♂	♂	♂	♂	♂	♂	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♂	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	♀	?	?	?
Vegetable	*Acnanthes*					r		r				r		r	r		r	r				r			r				r																							
	Amphiprora													r					r						+																r			+	+							
	Amphora					+					c	c					+		r			r																														
	Bacillaria														+																										+						r		r		r	
	Biddulphia			r	r	r			+	r				r	r		+	r	r		r	+	r		r				+	r	r		+		r	+	r	r			r	+	r		r		r				r	
	Campylodiscus			r	r	c		r	r		r	+			c		+			+	c		r						r				+			+	+		r	r		+		r		r	r					
	Cocconeis					+						+					r			r																																
	Colletonema																r																																			
	Coscinodiscus		r	r		r	r	r				+			+	r		r				r	r																		r		r				r					
	Cyclotella			+				r	+			c		+	r	+		r	+	+		c	r	+	+					+	r	r	r		+	r	+	+				+	c	+	+	r		r				
	Epithemia											r																																r	r							
	Gyrosigma	r						r			r	r								r																					r				r							
	Mastogloia																r																															r				
	Melosira	r	r					r				r			r			r		r		r							r								r				r		r	r								
	Navicula	r	c			+	r		r		r	c	r	+		+		r	+	+				r		r		r	r				r			r						+	r	+	+		r	r		r		+
	Nitzchia	r				c			r		+	c					r			r				r																	r				r	r	r	r	r			
	Pinnularia	r	c	+	+	+	r	+	c	r	+		+	+	c		+		+	r		+	+		+	+	r		c			r	+			+	+	c	+			+	r	+	+	r						+
	Pleurosigma	r						r			r	r							r	r		r													r	r					r											
	Surirella				r		r										r					r							r							r	r	r														
	Certain diatoms					c					+																r																							r		
	Algal plants	+	c	c	c	c	+		+	r			c	c	r	c	+	+	c	c		+	c	c	+	+			c	r	r		c	r	+	c	+	+	c	+		+	+	r	c	+		+		+	r	
	Desmids		r			r	r						r	r	r		r		r			r		r									r		r		r				r									r		
	Dinoflagellates		r					r	r		r	r			r			r	c		r	r			r	+			r	r	+			r	r		r					r	r	r								
	Oscillatoria	r				r	+		+		r					+				+		r	+	c							+				+			+					+	+			r	r				
Animal	Protozoa												r						r	r									r	r					r				r													
	Foraminifera																				+																															
	Cypridies																				+																															
	Cyclops											r																																								
	Certain copepods											r									r																															
	Nauplius larvae											r																																								
Dead matter	Sand grains										c		c				c				c						c													r								r	r			c
	Organic debris																										c																						r			c

mucous membrane of each organ, the oesophagus, stomach, intestine and pyloric appendages. Okamoto (1917) made a report only on the form of stomach. Sakura (1921) studied this fish from the standpoint of fish-culture. In order to determine the correct food with which to feed it, he made a histological observation of the external and internal characters of the stomach. Recently, besides Pernkopf (1930) who wrote about the muscular stomach for the second time, Ghazzawi (1933) examined the feeding habits of this fish and *Mugil capito* caught in Egyptian waters and at the same time made a histological observation of the digestive organ of the latter.

Liver, 2 lobes, rather small, hangs over the stomach, covering it partly. Gall-bladder, small, spherical, Ductus choledochus and D. cysticus both being short. Pancreas well developed, spreading between the intestine.

B. Feeding Habits.

There is a fine report on the feeding habits of this fish by Ghazzawi (1935) who examined the stomach contents of *Mugil cephalus* and *Mugil capito* caught in Egyptian blackish waters. Tab. 12 is from his report, which I have condensed into a table-form.

It will be seen from the table that the gray mullet feeds chiefly on seaweeds or diatoms at the bottom of the sea. He points out the suitableness of its stomach for digesting diatoms, and that the long intestine is an indication of herbivorous habits. He also says that the sand particles in the stomach is nothing else than to show that it takes bottom food. From my examination of the stomach contents of 5 fishes obtained from the Tokyo Fish Market on 30th March, 1928, I found that they all had taken a good quantity of mud and that in this mud, there was a tolerable amount of Isopoda and large number of diatoms.

Family ATHERINIDAE

45. *Atherina bleekeri* (Günther): Tôgorôiwasi.

A. Digestive System.

Body rather elongate, somewhat compressed. Mouth moderate (m-c being ca. 1/4 and m-b ca. 1/5 of head length), slightly upwards: premaxillary well developed and protrusile; jaws and the vomer armed with rudimentary teeth; no teeth on the palatines. Mouth cavity moderately large; tongue elliptic, very thin, free, teeth and melanin chromatophores both absent on the tongue. Pointed minute teeth on the 2 sets of front and back pharyngeal bones and 1 set of the lower pharyngeal bone. Gill-rakers long (a little longer than corresponding gill-filaments), tips pointed, flat, coarse, 28-31 in number, process numerous.

Peritoneal cavity rather large, much space; peritoneum black. Oesophagus comparatively large; there being no stomach, oesophagus connects directly to the intestine. Intestine short (the length being ca. 1.3 times o~a), rather wide, especially at the beginning; wall very thin; as illustrated, makes 1 coil, Coiling such as this is very rare in the winding-type of the fish intestine. The

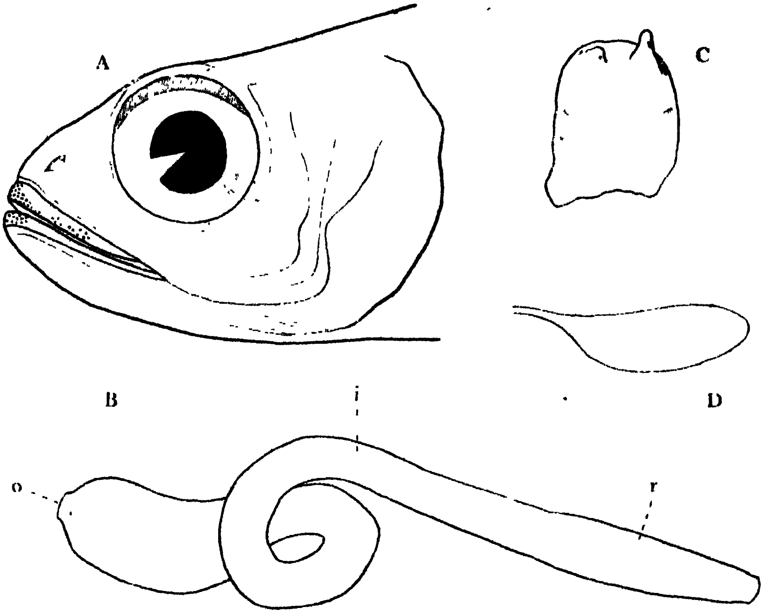


Fig. 65. *Atherina bleekeri.* A. Head. B. Digestive tract. C. Liver. D. Gall-bladder.

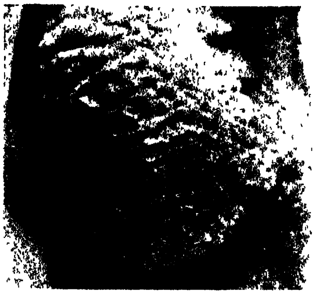


Fig. 66. *Atherina bleekeri.* Folds of mucous membrane of intestine.

oesophagus and the intestine may be distinguished by their reliefs, that is, the former consists of 30 longitudinal folds and the latter of the papillary processes. The intestine is divided by a valve into the middle intestine and the rectum. The anus opens in the middle part between the right and left pectoral fins, which is the special character of this species.

Liver not large but thick, the weight being ca. 1/25 of the body weight; consisting of 2 lobes, the right is a little longer than the left; located just below the beginning of the intestine. Gall-bladder small, ellipsoidal; the bile duct opening at the beginning of the intestine. Spleen small, situated on the right side of the middle part of the intestine.

B. Feeding Habits.

Through the courtesies of Prof. I. Amemiya and Mr. S. Murayama, I was able to examine 50 of this fish from the Misaki Marine Biological Station, and 20 more from Nagai, Kanagawa Prefecture, through Mr. K. Harada's courtesy, and found that it ate very little, and that its food consisted principally of copepods and other zoo-plankton. It does not seem to go in particularly for the phytoplankton, such as the diatom.

Table 13

Stomach contents of *Atherina bleekeri*

Date	Apr., 1934	June, 1932	Frequency
Locality	Nagai, Kanagawa Pref.	Misaki, Kanagawa Pref.	
Number of fish	20	50	
Body weight (g)	—	8.6 ~10	
Body length (cm)	10.2 ~15.4	11~14	
Stomach contents			
Certain copepods	8	15	23
Corycaeus	1	3	4
Microsetella	2		2
Oithona	4	9	13
Oncea	1	4	5
Paracalanus	11	35	46
Sapphirina		7	7
Nauplius larvae		1	1
Ostracoda	1		1
Rotatoria	1		1
Certain insects	2		2
Eggs of *Atherina* (?)		2	2
Coscinodiscus		1	1
Spores of sea-weeds		2	2
None	7	12	19

46. ***Atherina tsurugae*** (Jordan et Starks): Gin'isoiwasi.

A. Digestive System.

A few days after examining the foregoing species, through the kind arrangements of Prof. I Amemiya and Mr. S. Murayama, I was able to examine some 30 of this fish caught near the Misaki Marine Biological Station. The results of this examination showed that the appearance of the present species, as well as the construction of its digestive system, do not differ very much from that of the previous one, except that the anus is located below the

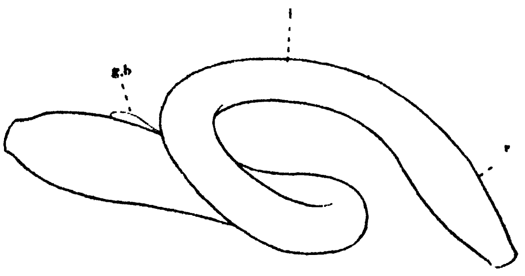


Fig. 67. *Atherina tsurugae.*

pectoral fins and not in the center between the 2 fins. This is the major point of difference. Another point of interest is that due to the anus being located towards the posterior part, the intestine of this fish does not make the circular turning of the foregoing species but in the form of an N. This, I believe, has to do with the distance of the oesophagus and the anus as against the length of the intestine.

Family ZEIDAE

47. *Zeus japonicus* (Cuvier et Valenciennes): Matôdai.

A. Digestive System.

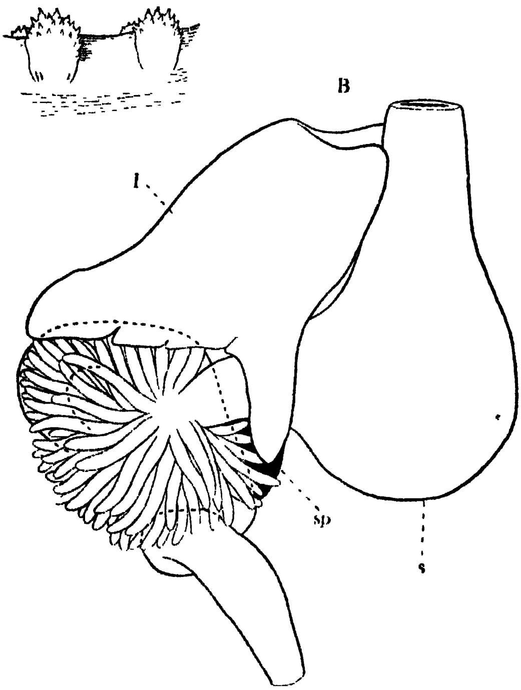


Fig. 68. *Zeus japonicus*. A. Gill-rakers. B. Digestive tract.

Body orbicular, very much compressed. Mouth large (m-c being ca. 2/5 and m-b ca. 1/6 of head length), lower jaw longer than the upper. Minute, conical, pointed teeth grow in bands in each jaw. Buccal cavity rather small; no teeth on the vomer and palatines; folds of the palatal mucous membrane longitudinal. Tongue rather large, triangular, thick, smooth, a few melanin chromatophores on the surface. (Pl. III, Fig. 15). Pharyngeal teeth rather large, sharp, and conical, arranged in 3-pair sets. Gill-rakers degenerate, forming about 15 bunches of setae as shown in the figure.

Peritoneal cavity rather large but compressed; peritoneum silvery. Oesophagus tolerably long (Meckel (1829) also recognizes this in the case of the oesophagus of *Zeus faber*), wall thick, the mucous membrane consisting of some 12 longitudinal deep-grooved folds and shallow-grooved longitudinal folds between each deep-grooved fold. The stomach consists of a rather long and broad cardiac part, a large spherical but more or less compressed blind sac, and a short pyloric part. Regarding the fact that *Zeus* has such a characteristic blind sac, Cuvier (1810), Meckel (1829), Eggeling (1907), Pernkopf (1930), etc. have already described it. Wall of the stomach thick, the mucous membrane of the cardiac part almost flat, that of the blind sac assumes longitudinal serpentine folds with a net-work between each, and that of the pyloric part ordinary longitudinal folds. Intestine considerably short and narrow, wall thin; makes 1 large circular turning and bends once as shown in the illustration. The mucous membrane of the intestine consists of net-work folds. The anus opens just in front of the anal-fin. Pyloric appendages short, 120 to 130 in number.

Liver large and thick, consists of 2 lobes, the left being somewhat larger. Gall-bladder, a rather large oval, located between the lobes of the liver near the pyloric part of the stomach. Bile duct moderately long. Spleen thin, medium in size, situated near the pyloric part.

B. Feeding Habits.

I examined the stomach contents of 2 of this species which were collected by Mr. S. Miyauti from the adjacent waters of Aziro, Sizuoka Prefecture, on May 8th, 1937, and found that one of them had eaten the fishes which belong to Platycephalidae and the other certain fishes.

Family BERYCIDAE

48. *Beryx splendens* (Lowe): Kinmedai.

A. Digestive System.

Body rather elongate, compressed. Mouth large (m-c being ca. 1/3, m-b ca. 1/4 of head length), directed obliquely (ca. 45°) upwards; bands of minute conical teeth in both jaws. Mouth cavity very large; the buccal mucous membrane reddish; villiform teeth grow in bands on each palatine. Tongue red in colour, small, triangular, thin, free and smooth. Pharyngeal teeth small, larger than the jaw teeth, closely set on the 3 sets of the upper and 1 set of the lower pharyngeal bones. Gill-rakers long (a little longer than corresponding gill-filaments), grow at right angles to the gill-arch, tips pointed, coarse, 25 in average number, process on a gill-raker numerous.

Peritoneal cavity large; peritoneum black. Oesophagus short and with thick wall, the mucous membrane consists of 11 longitudinal folds. Stomach rather small, ┤-shape, wall thick (pyloric part having the thickest wall), the mucous membrane assumes 11 to 12 of ordinal longitudinal folds; development of blood-vessels conspicous on the stomach. Intestine long (the length being ca. 2.8 times of d∼a), begins from rather wide duodenum, making 2 large windings and 1 short bending, ends to the narrow rectum; the wall rather thin, and the mucous membrane consists of irregular zigzag folds. Pyloric appendages long and broad, situated on the left side of stomach, 31 in number.

Liver large, consisting of 2 lobes, the left one larger, located below the anterior part of stomach. Gall-bladder large, long ellipsoidal, bile duct not long. Spleen 2, situated near the rectum. Pancreas diffuses along the blood-vessels and between the pyloric appendages. Air-bladder elongate, rather large, the wall thick.

According to the report of Cuvier and Valenciennes, *Beryx lineatus* has a cylindrical V-shaped stomach and about 20 pyloric appendages.

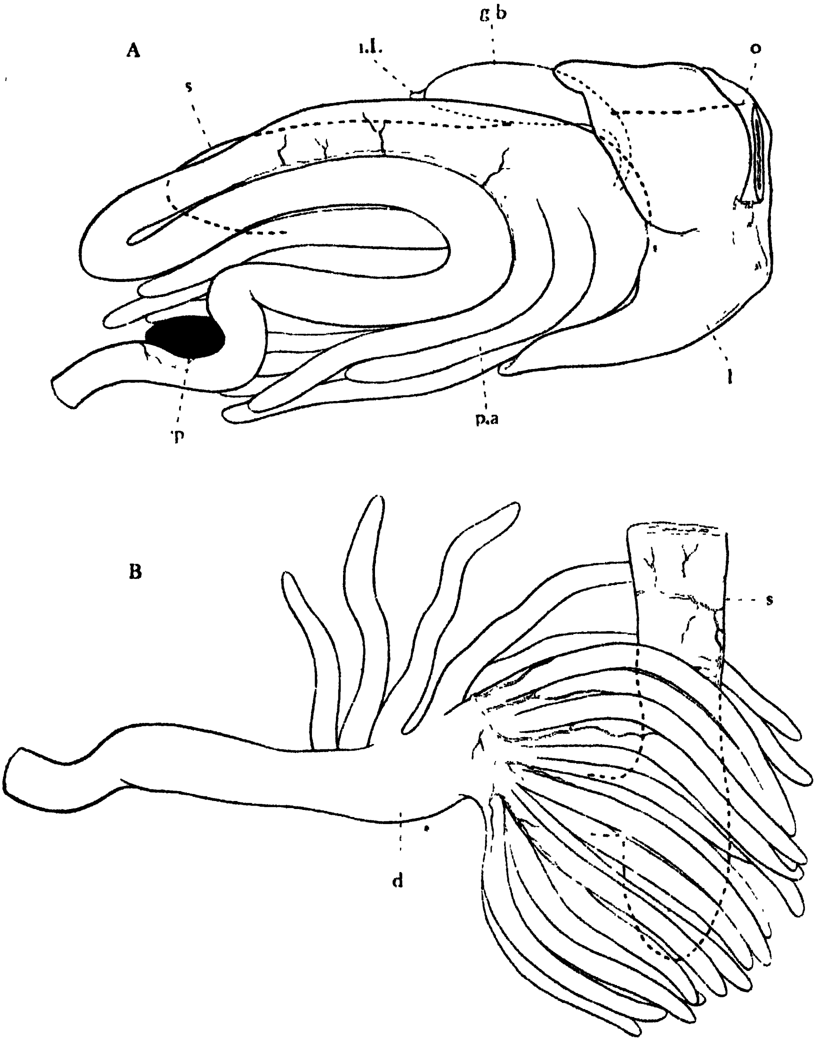


Fig. 69. *Beryx splendens* A. Digestive tract. B. Pyloric appendages.

B. Feeding Habits.

It would be worthy of note that the fishes, 31.5 to 33.8 cm in body length, which I collected at the Tokyo Fish Market on Feb. 17, 1939, had taken chiefly the lantern fishes.

Family MONOCENTRIDAE

49. *Monocentris japonicus* (Houttuyn) : Matukasauwo.

A. Digestive System.

Body short, deep, compressed ; scale very large and hard. Head large ; mouth rather wide (m-c being ca. 2/5, m-c ca. 1/3 of head length), slightly inferior. Teeth in jaws degenerate, but as the jaws themselves are so hard, it should not be difficult to imagin that they can serve the purpose of biting off the baits. Mouth cavity medium in size; the folds of palatal mucous membrane longitudinal; villiform teeth on palatines, but none on vomer. Tongue large and soft, semi-circular, thick, smooth, no melanin chromatophores. Pharyngeal teeth very minute, but they form a pair of stout masses. Gill-rakers long (the length being ca. 4/3 of corresponding gill-filaments), broad, tips blunt, closely set, 19-20 in number.

Peritoneal cavity large, ellipsoidal; a few melanin chromatophores scattered in the peritoneum. Oesophagus short; stomach large, V-shape; cardiac part large and wide, pyloric part also large, but blind sac degenerates. The folds of the mucous membranes of oesophagus and stomach both longitudinal. Intestine moderately long (the length being ca. 3 times d~a) and bends twice, the mucous membrane consists of transversal serpentine folds. Pyloric appendages very long, 6 in number.

Liver rather large, 1 lobe, located on the left side of stomach. Gall-bladder small. Air-bladder very large and stretched.

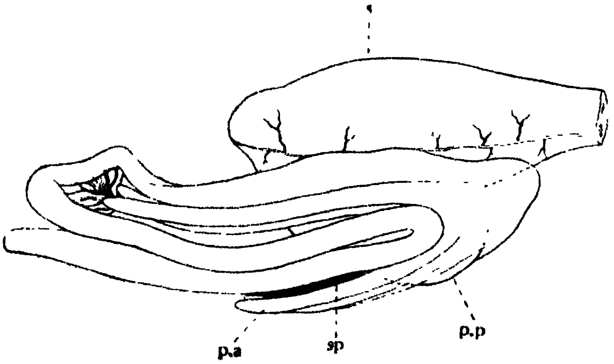


Fig. 70. *Monocentris japonicus.*

B. Feeding Habits.

According to the book written by Amemiya and others (1933, p. 187), this fish lives usually in a pretty deep waters or behind rocks, and seeks actively for its food in a dark night.

Family SCOMBRIDAE

50. *Scomber japonicus* (Houttuyn): Saba.

A. Digestive System.

Body fusiform and compressed, its height nearly equal to the length of the head. Mouth rather large (m-c being ca. 1/2, m-b ca. 1/6 of head length), horizontal. About 60 minute conical teeth grow in a series in each jaw. Mouth cavity moderately large; 2 or 3 rows of minute teeth exist on each palatine; vomer also armed with minute teeth. Tongue medium in size, triangular, pointed, thin but hard, free, no teeth, rich in melanin chromatophores. Pharyngeal teeth long but very slender, numerous, resembling closely a scrubbing-brush. Gill-rakers long (the length being ca. 3/2 of corresponding gill-filaments), flat, tips blunt, closely set, 35–38 in number, process on a gill-raker about 40.

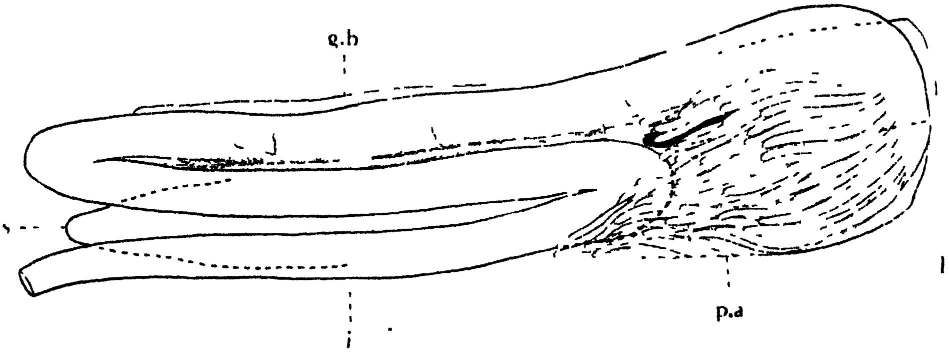


Fig. 71. *Scomber japonicus*

Peritoneal cavity rather small; oesophagus short, the wall thick, the mucous membrane consists of about 25 longitudinal folds having a great deal of short transversal ridges on each fold. Stomach large, ˥-shape; blind sac so long that its tip reaches to the end of the peritoneal cavity. Mucous membrane of the stomach consists of 12–15 longitudinal somewhat serpentine folds. Intestine moderately long (the length being ca. 3 times d~a), winds twice, forming N-shape, rather broad, wall not thick, the mucous membrane consists of longitudinal folds with vertically waved ridges (Pl. IX, Fig. 4.). A valve exists between the middle intestine and the rectum. Pyloric appendages long and slender, about 150 in number.

Liver very small, 1 lobed, situated below the cardiac part of stomach; gall-bladder very long and its tip reaches to the end of the blind sac. Air-bladder large, fusiform, pointed at both ends.

There is quite difference between the digestive organs of this fish and those which belong to the Katsuwonidae and Thunnidae, which will be described in the next chapter. It is to be noted that they are more like those of Carangidae (note especially the pyloric appendages and liver).

As for the digestive system of this fish, Okamoto (1918) made an accurate report on its stomach only, while Kishinouye (1923) rendered a somewhat detailed description of the construction on each organ. Not only did Cuvier and Valenciennes study the digestive system of *Scomber scomber* but Rathke (1820), Eggeling (1907) and many others followed suit. Jacobshagen (1911) also made a complete study of it. Your attention is drawn to the paragraph where he says: "Mittel- und Enddarm sind ziemlich von gleicher Weite, die ziemlich gering genannt werden muss. Beide Abschnitte werden getrennt durch eine Bauhinsche Klappe, die äusserlich durch eine Einschnürung kenntlich wird".

B. Feeding Habits.

Among the many studies of Kishinouye (1923) regarding the Scombroid fishes, there is a report on the food of *Scomber japonicus*, in which he says: "Scomber is also a plankton-feeder, but its food differs in different seasons and localities. In bays the fish is omnivorous, and feeds near the bottom; but in the open sea it seems to feed near the surface", which, in my opinion, is impartial in his opinion. Kasamura (1925), after examining the stomach contents of 48 adult mackerels collected in the vicinity of Toyama Bay, found that they consisted chiefly of ***Euphausia***. There are other reports in this connection, such as the work of Bullen (1908) who studied the feeding habits of European mackerels and stated that planktonic Crustacea constituted its chief food and the work of Marukawa (1912) who said that its food was Crustacea and small fishes, all of which make, in my opinion, good reading.

Family KATSUWONIDAE

51. *Katsuwonus vagans* (Lesson): Katuwo.

A. Digestive system.

Body elongate, compressed. Head somewhat pointed. Mouth large (m-c being ca. 1/3, m-b ca. 1/5 of head length); lower jaw a little longer than the upper. 1 row of very minute conical teeth in each jaw. Mouth cavity rather large; folds of palatal mucous membrane longitudinal; no teeth on the vomer and palatines; tongue moderately large, rectangular, rimmed on both sides, silvery, and rich in melanin chromatophores. No teeth. Pharyngeal teeth rather long and pointed, constituting a pair of tooth-band on the upper and lower pharyngeal bones. Gill-rakers long (the length being ca. 1/5 of corresponding gill-filaments), flat, tips pointed, vertical to the gill-arch, 50 in average number.

Peritoneal cavity rather small; melanin chromatophores hardly any on the peritoneum. Oesophagus short, wall thick. Stomach ┐-shape, wall thick; blind sac long, narrowing as it gets toward the end; mucous membrane of the stomach, 30 longitudinal folds having numerous short transversel ridges closely set together. Intestine short (ca. 1.2 times d~a), runs almost in a straight line, the beginning of which, that is, the duodenum, curves in a U-form, and the latter part is the rectum separated by a valve; wall thick; mucous membrane, papillary processes in about 10 vertical rows; that of the rectum, as shown, being a little different. The pyloric appendages of this fish, differing from those of any foregoing species, are extremely short, the numerous appendages (it might be more appropriate to call them glands) being wrapped in a mucous membrane, which is often mistaken for the liver, below the stomach to the right.

Liver moderately large, reddish in colour, 3 lobes, the right being longer than the left, situated below the cardiac part. Gall-bladder long and slender, the tips stretching to the end of the blind sac of the stomach. Air-bladder long and fusiform.

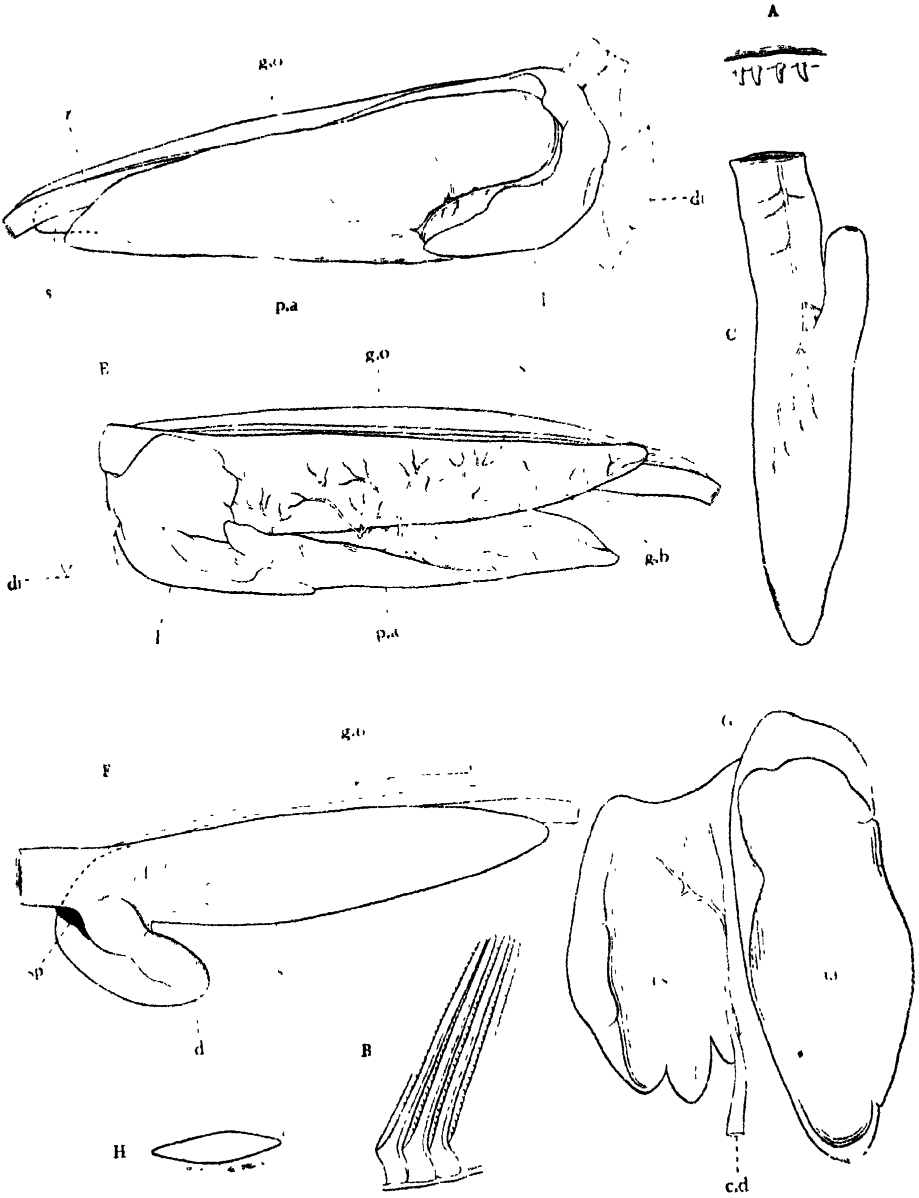


Fig. 72. *Katsuwonus vagans*. A. Jaw teeth. B. Gill-rakers. C. Stomach. D. Right side view of digestive tract. E. Left side view of digestive tract. F. Stomach and duodenum. G. Liver. H. Anus.

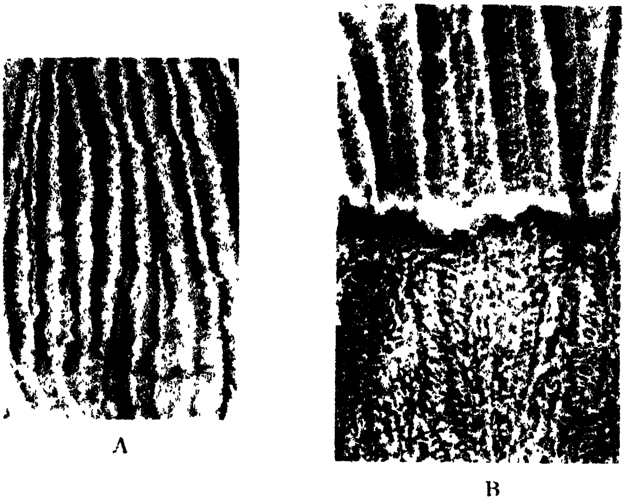


Fig. 73. *Katsuwonus vagans.* Folds of mucous membrane. A. Stomach. B. Intestine (upper) and rectum (lower).

B. Feeding Habits.

The earliest reports on the feeding habits of this fish are those made by Okamura and Marukawa (1909) who examined the stomach contents of this fish collected from the various Fisheries Experimental Stations throughout Japan and found that its chief food consisted of rather large Crustacea, Gastropoda, sardines and so forth. The examination of the stomach contents of bonitos by Yanagi (1911), collected from the coasts of Miyagi, Hukusima, Ibaraki, Sizuoka, Miye, Wakayama, Kôti and Miyazaki Prefectures, showed that they fed mainly on sardines, amphipods and schizopods being taken as side-food. I am, however, of the opinion that the sardines which had been eaten were the baits used for fishing bonitos. Kishinouye (1923) expressed the opinion that the principal food of this fish was fishes, Crustacea and Mollusca. Uda (1933) completed an interesting study on the connection the stomach contents of this fish had with the manner in which it went after baits at the time it was being fished.

As already reported (in 1938), the results of my efforts showed, after examining the fishes collected by the fishing boats of Miyagiken Fisheries Experimental Station, including 8 other prefectural stations, and those obtained through the courtesy of Mr. M. Uda, that the principal food of this fish was cuttle-fishes, shrimps, schizopods, amphipods, etc., as shown in the table. Furthermore, there is a group of this fish that lives in shallow places of the open sea, while the other group migrates from sea to sea. The former eats almost anything, but the latter chiefly planktonic Crustacea, sardines and cuttle-fish found in the ocean. Another point of interest in this connection is that while the former can always find food when it wants to eat, the latter is pretty nearly always hungry.

Table 14

Stomach contents of *Katsuwonus vagans*

Date	May 28, 1936	June 3, 1936	July 1, 1936	July 19, 1936	July 21, 1936	July 3, 1937	July 8, 1937	July 9, 1937	July 10, 1937	July 11, 1937	June 5, 1936	May 21, 1936	May 26, 1936	May 28, 1936	June 1, 1936	June 2, 1936	June 3, 1936	June 3, 1936	June 29, 1936	June 27, 1937	Oct. 10, 1937	Oct 24, 1937	May 6, 1936	May 7, 1936	May 28, 1936	May 29, 1936	June 5, 1936	Frequency
Locality	33 07′ N 113 10′ E	33 25′ N 111 05′ E	35 10′ N 147 08′ E	37 40′ N 115 11′ E	38 15′ N 113 15′ E	35 37′ N 111° 58′ E	37 54′ N 147 15′ E	38 21′ N 118 12′ E	39 21′ N 119 10′ E	39 02′ N 115 05′ E	27 55′ N 111 57′ E	32 27′ N 139 55′ E	32 37′ N 139 40′ E	33 13′ N 140 20′ E	23 09′ N 126 21′ E	24 12′ N 125 25′ E	21° 19′ N 125 36′ E	24° 06′ N 125° 35′ E	25° 31′ N 128° 11′ E	25° 37′ N 125° 59′ E	27 08′ N 127° 20′ E	25° 29′ N 126° 18′ E	26° 52′ N 140° 51′ E	25° 24′ N 141° 20′ E	33° 38′ N 144° 07′ E	32° 51′ N 143° 56′ E	26° 05′ N 141° 04′ E	
Number of fish	10	10	10	10	10	14	1	1	1	1	4	3	10	5	10	3	1	12	14	5	10	10	8	3	9	20	7	
Av. body weight (g)	2228	1727	1150	2679	2990	1750	—	—	—	--	–	1814	1525	1585	1070	4980	6500	1190	2740	6940	6110	3440	2087	—	1901	—	3853	
Av. body length (cm	44.5	42.0	39.0	44.0	40.0	41.0	—	-	-	—	--	43.2	41.0	40.8	38.0	63.0	72.1	40.0	46.0	64.4	48.8	54.3	48.7	—	47.1	—	52.5	
Av. weight of stomach contents	4.2	19.1	10.8	7.3	7.3	28.2	-	-		—	-	1.7	2.7	6.7	1.6	35.0	0	17.1	9.9	4.1	12.0	11.0	33.5	10.8	26.5	37.0	10.6	
Clupeoid fishes			6									1	5	1				1	2									16
Sardinia melanosticta	1	8	1	3	3									1									7			3	2	29
Engraulis japonicus	2	2	2			7			1		3		3	2	4	1		9	3	5	9	7			6	12	1	79
Bones of fishes	2				1	2					1					2		1	3				2		2			16
Young fish of bonito																										1		1
Mackerels																										2		2
Trachurus japonicus						6							1											1			1	9
Lantern fishes		2																						3		3		8
Cypsilurus agoo														1				1										2
Cuttle-fishes																									2			2
Jaws of cuttle-fishes	1	1																				2						4
Symplectotenthis oualaniensis																							1					1
Pyrogopsis pacificus			1																									1
Shrimps	2						1																					3
Sergestes prehensilis													1												1			2
Megalopa larvae of crabs														1											1	2		4
Schizopoda							1	1				1	5	2									3					13
Amphipoda																									2			2
Indistinct				1						1																		2
None	4		2	6	6	1						1			5		1	1	2	5	1	1	1		1		4	42

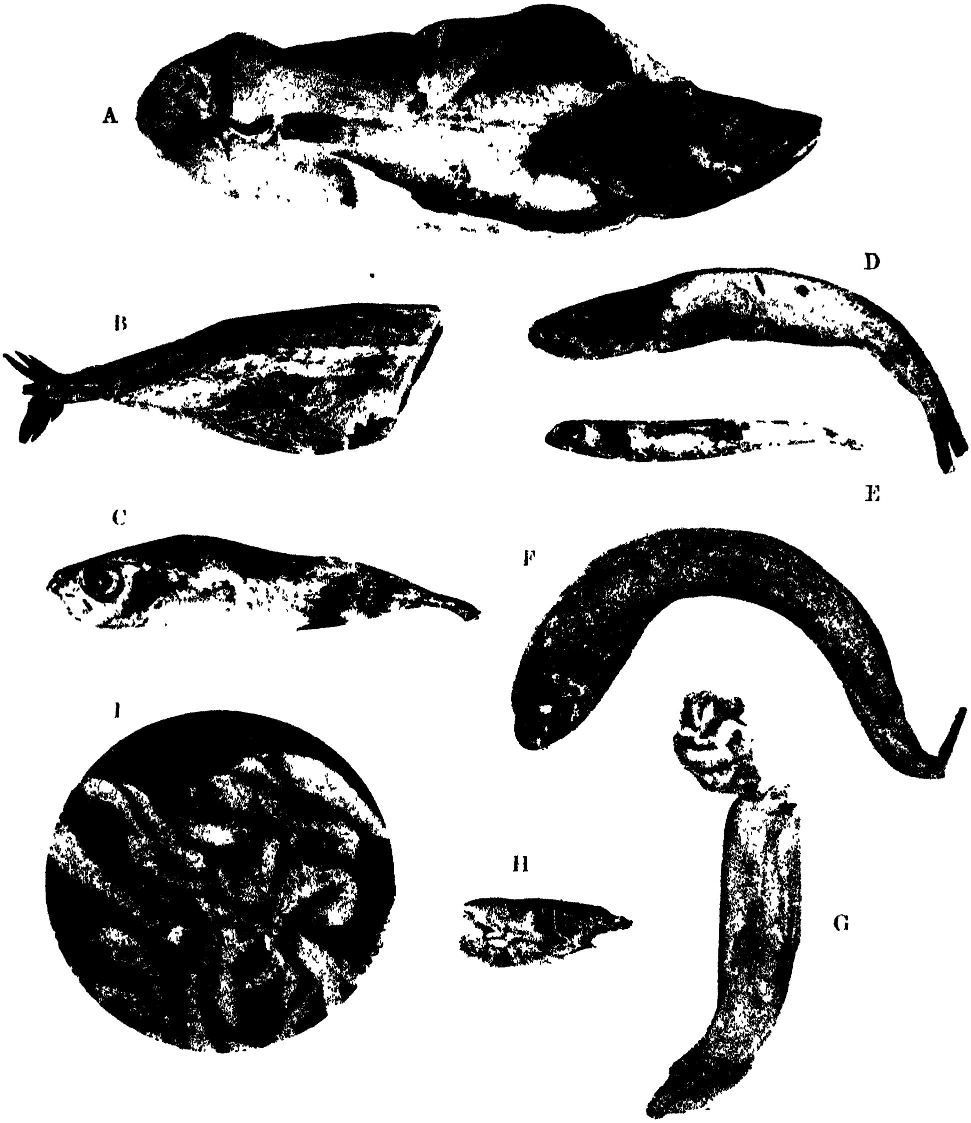


Fig. 74. Stomach contents of *Katsuwonus vagans*. A. Mackerel in the stomach of bonito. B. Young fish of bonito. C. *Trachurus japonicus*. D *Sardinia melanosticta*. E. *Engraulis japonicus*. F. Flying-fish. G. Cuttle-fish. H. *Sergestes*. I. Schizopods.

Family THUNNIDAE

52. *Thunnus orientalis* (Temminck et Schlegel): Maguro.

A. Digestive System.

Body fusiform; head somewhat triangularly pyramidal. Mouth moderate (m-c being less than 1/3, m-b ca. 1/2 of head length), turns slightly upwards. A row of villiform teeth in each jaw, also on the palatines. Buccal cavity rather large; tongue tolerably large (note that the tongue of Scombridae mentioned above is small), trapezoid, flat, rather thin, free, greyish and armed with rudimentary teeth. Pharyngeal teeth villiform. Gill-rakers well developed, moderately long (the length being ca. 1/2 of corresponding gill-filaments), flat, tips rather pointed, 36 to 39 in number, process numerous.

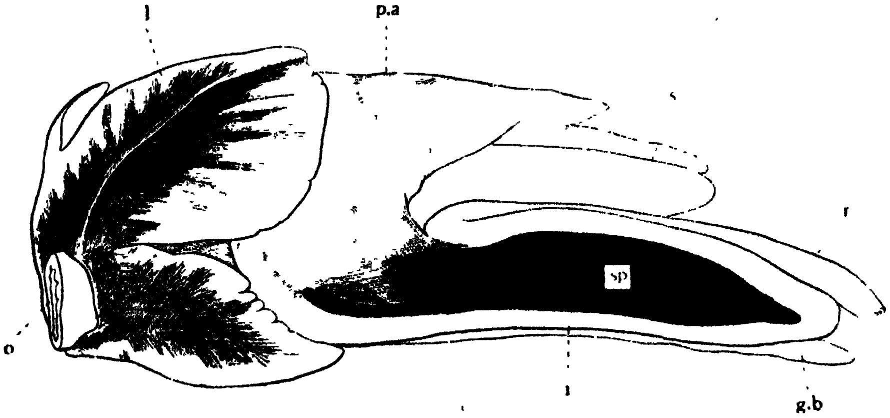


Fig. 75. *Thunnus orientalis.*

Peritoneal cavity moderate; peritoneum thick and greyish in colour. Oesophagus broad but short. Stomach large, ˥-shape; the cardiac part and the blind sac together forming 1 fusiform sac. The length from the end of the blind sac is approximately 2/5 of the body length. The end of the blind sac is somewhat pointed. Wall of the stomach thick and sufficiently distensible; pyloric part short, being more muscular than the sac-portion. Mucous membrane of the stomach usually consists of 30 to 40 wide and narrow longitudinal folds.

Intestine moderately long (the length being 3/2 of d~a), winds twice forming N-shape; wall thick, moderately broad; the rectum being at the end of the intestine. Mucous membrane of the intestine consists of papillae. The pyloric appendages of this fish are similar to those of the mackerel and bonito, that is, a great number of appendages cluster together and form 1 big mass which is covered by a membrane.

Liver thick, consists of 3 lobes (each lobe being short and almost the same length; the left and right lobes being subdivided into 3 lobes) and overhangs the cardiac part. The characteristic point about the liver is that on the surface, there is a dense distribution of minute veins. The gall-bladder is the same as that mentioned above, long-stretched. Spleen large, situated at the first winding of the intestine. Air-bladder triangular.

As for the digestive system of this fish, there is an excellent report by Kishinouye (1923). As for the foreign *Thunnus*, there are the work of Cuvier (1803), Eschricht and Muller (1835: Liver), Bridge (1904: Pyloric Appendages), and Regan (1909: General).

B. Feeding Habits.

Kishinouye (1923) writes on p. 400 of his paper about the feeding habits of this fish as follows: "It feeds on different kinds of fish, more or less pelagic in habit, such as sardine, anchovy, flying fish, scad, sand-eel, etc., but sometimes fishes living near the bottom are found in the stomach. Calamaries and Pteropods; *Pyrosoma*; pelagic crustaceans, such as *Euphausia*, *Sergestes*, *Acanthephyra*, larvae of Brachyura and Stomatopoda, anomolous Amphipoda, etc. are also found in the stomach". And according to the Hokkaidô Fisheries Experimental Station (1928), the food of this fish are small herrings, sardines, cods, etc. Hujii (1932) said that this fish went migrating in pursuit of sardines and herrings, which is known as "feeding-migration", and that when it jumped from the water, the action was caused on account of its

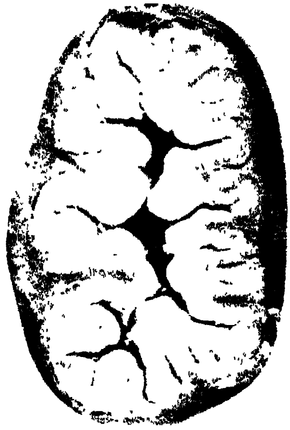


Fig. 76 *Thunnus orientalis*. Cross section of oesophagus.

Table 15

Stomach contents of *Thunnus orientalis*

Date	Nov. 22, 1935	Nov. 21, 1935	Frequency
Locality	:	Off the coast of Sanriku	
Number of fish	28	23	
Stomach contents			
Certain fishes	2	1	3
Vertebra, etc. of fishes	8	10	18
Clupeoid fishes	2	3	5
Maiwasi (*Sardinia melanosticta*)	5	9	14
Katakuti-iwasi (*Engraulis japonicus*)	3	3	6
Flying-fishes		1	1
Cuttle-fishes		1	1
Jaws of cuttle-fishes	3	3	6
Hôzuki-ika (*Liocaranchia reinhardtii*)	2		2
Certain Paguridae	1		1
Straws		2	2
Indistinct	1		1
None	6	9	15

jumping on its prey. He maintained that the swordfish jumped for recreation but the present species jumped out of necessity. The Hyôgoken Fisheries Experimental Station (1935) maintained that this fish migrated in pursuit of flying fish, occasionally jumping out of the water.

In 1935, through the kindness of Mr. I. Tukamoto, I was able to examine 51 stomachs of this fish collected off the coast of Sanriku. As shown in the table, I found that they contained principally fishes, especially sardines, but at the same time, many were empty, which I believe is something worth nothing.

53. *Parathunnus sibi* (Temminck et Schlegel): Mebati.

A. Digestive System.

There is not such a great deal of difference in the digestive system of of this and the foregoing species, but I shall describe the differences as they are: first, the tongue is somewhat smaller; the number of gill-rakers 26 to 28; folds of the mucous membrane of the stomach about 25 longitudinal serpentine folds; the intestine being a little longer than the previous species. 3 lobes constitute the liver, the same as in the foregoing case, but the left and right lobes are not subdivided as in the case of *Thunnus*, nor is there any distribution of minute veins on the surface.

B. Feeding Habits.

On page 444 of his paper, Kishinouye (1923) writes as follows regarding the feeding habits of this fish: "Very voracious fish, feeding on sauries, bonitos, luminous fishes, such as *Maurolicus*, and allied kinds, cuttle-fish, Amphipoda, *Sergestes*, *Acanthephyra*, etc."

In 1935, when we went out on the Pacific Ocean on the "Fuzimaru", one of the fishing boats of the Sizuokaken Fisheries Experimental Statian, on the 21st of June, 34°28′ N. and 144°40′ E., we caught this fish. On examining 5 stomachs (43.7 cm–2620 g to 48.5 cm–2820 g), I found that they all had eaten sardines (although some of the sardines were those used for baits). On May 6, 1936, Mr. M. Uda turned over to me that which (58 cm, 4460 g) he had caught near Nisinosima, Ogasawara, and I in turn examined its stomach contents. I found that it had eaten 16 sardines (although they might have been bait-sardines). When Mr. H. Marukawa examined the stomach contents of a sample caught by the Awomoriken Fisheries Experimental Station on June 18, 1938, 34 51′ N. and 175°04′ E., he found among them Takoika (*Gonatopsis borealis*), Tobiika (*Symplectoteuthis oualaniensis*), Okizayori (*Tylosurus annulatus*), etc.

From the results of researches mentioned above, it would seem that this fish has the habits common to the so-called Scombroid fishes, that is, while they are of the same stock, one goes migrating in pursuit of food while the other looks for food in shallower spots (near rocks) in the ocean and stay there.

54. *Neothunnus macropterus* (Temminck et Schlegel): Kihada.

A. Digestive System.

The differences in the digestive system of this fish in comparison with the 2 foregoing species are as follows:--

Gill-rakers 30; although 3 lobes constitute the liver, the left is subdivided into 2 small lobes and the surface is devoid of minute veins.

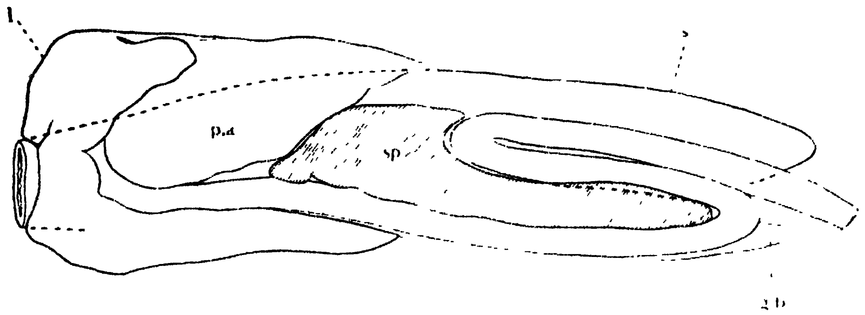


Fig 77. *Neothunnus macropterus.*

B. Feeding Habits.

Examination of the stomach contents of the sample caught on Sept. 4, 1937 at 27°14′ N. and 141°57′ E. by fishing boat of Sizuoka Prefecture "Kaizin-maru" revealed that they consisted of Sokoharigoti (*Hoplichthys gilberti*), *Erilepis* sp., other fishes, and sea-slugs. The samples examined by Mr. S. Saitô, collected near Timor Island in Dec. 1937, had taken leather-fishes, cuttle-fishes, shrimps, etc. Perhaps this was because they were a group which had gathered near the rocky bottom of that vicinity.

According to the report of H. Nakamura (1936), the fishes which were caught in 1933 and 1934 from the Celebes Sea, took mainly fishes (*Engraulis, Ostracion, Balistes, Sphyraena, Tylosurus, Stolephorus*, etc.), cuttle-fishes, Crustacea, etc.. Moreover, they can be divided into 2 groups, according to their stomach contents, that is, a group that gets its food along the coast, and another group that obtains its food in the open sea.

Family CYBIIDAE

55. *Sawara niphonia* (Cuvier et Valenciennes): Sawara.

A. Digestive System.

Body much elongate, compressed. Mouth large (m-c being ca. 2/5 of head length), slightly oblique upwards. Teeth in jaws large, flat and sharp, about 25 in the upper and about 20 in the lower. Mouth cavity medium in size; villiform teeth on vomer and palatines; tongue large, semi-circular, free anteriorly and laterally, rich in melanin chromatophores, no teeth (tongue of *Sawara guttata* armed with teeth). Pharyngeal teeth very small but numerous. Gill-rakers moderately long (a little longer than corresponding gill-filaments), flat tips pointed, coarsely grown, about 15 in number, process on each gill-raker numerous.

Peritoneal cavity elongated; no melanin chromatophore on peritoneum. Stomach ˥-shape, wall thick, mucous membrane consists of 7 to 8 longitudinal

folds, Intestine slender, runs straight from duodenum to anus; it is divided into the middle intestine and the rectum; mucous membrane of the intestine consists of longitudinal zigzag folds. Pyloric appendages numerous, but they are fewer than those of Thunnidae and Katsuwonidae.

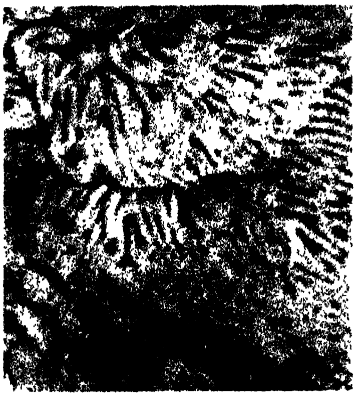


Fig. 78. *Sawara niphonia.* Pyloric appendages.

Liver rather small, situated under the anterior part of stomach, 3 lobes, the right one the largest; gall-bladder very long, stretching along intestine. No air-bladder.

B. Feeding Habits.

Hayasi (1919) observed the stomach of many fishes which were caught from the various parts of the adjacent waters of Kagawa Prefecture and found that they had taken mainly the sardines and sand-eels. According to Kishinouye (1923), this fish is voracious, and feeds chiefly on surface-swimming and school-making fishes, such as sardines, anchovies, sauries, mackerels, sand-eels, etc.

Family TRICHIURIDAE

56. *Trichiurus haumela* (Forskål): Tatiuwo.

A. Digestive System.

Body very much elongated and greatly compressed. Mouth large (m-c being almost 1/2 of head length); the lower jaw being longer than the upper. Teeth in jaws very large, sharp and flat, the tip being like a fishing hook as shown in Pl. I, Fig. 2. About 14 sets of teeth in the upper jaw, 2 of which in the anterior part especially large and about 15 sets in the lower, 1 tooth at the end being especially large, besides which there are numerous small teeth in the upper and lower jaws. Mouth cavity moderate; palatal mucous membrane light black; rudimentary teeth on the vomer and none on the palatines. Tongue moderately large, triangular, rather long, free, melanin chromatophores rather numerous, smooth, similar to the tongue of *Cololabis saira.* Pharyngeal teeth small and closely set in rows. Gill-rakers forked, very short and narrow (the length being ca. 1/6 of corresponding gill-filaments), coarsely grown (Pl. IV, Fig. 18).

The body is particularly long, but the peritoneal cavity is not so elongated in comparison; peritoneum silvery. Stomach very long, ⅂-shape; blind sac very long but the cardiac and pyloric parts are short; wall thick; mucous membrane consisting of 14 longitudinal folds (Pl. VII, Fig. 10). Intestine narrow, runs in a straight line; wall moderately thick; mucous membrane being net-work (Pl. X, Fig. 14). Pyloric appendages broad and rather long, located near the lower part of the stomach, 25 to 30 in number.

Liver large, consisting of 2 lobes, each lobe triangular; gall-bladder very

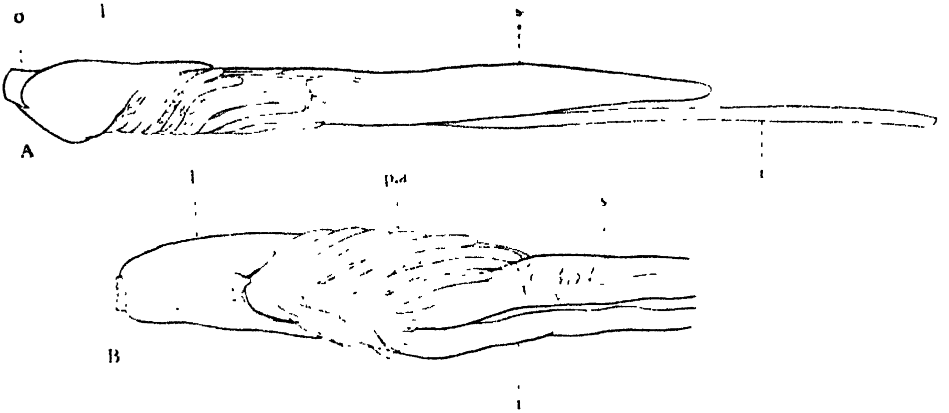


Fig. 79. *Trichiurus haumela.* A. Digestive tract. B. Pyloric appendages.

long, stretching along the intestine. Cuvier and Valenciennes stated that the stomach of *Trichiurus lepturus* was long, and that there were 23 pyloric appendages.

B. Feeding Habits.

I made a very rough observation on the material obtained from a fishmonger during the years 1933 and 1934. Of the 47 stomachs, over 1/2 of them, namely 28, were empty and the rest had in them pieces of *Trichiurus haumela* and cuttle-fish. This fish usually lives near the bottom but at night it comes schooling above the middle layer of the sea, but owing to its rather low swimming velocity in comparison with other fishes, it has difficulty in obtaining in food. Therefore, it is often found with an empty stomach. Further, it would seem that it eats one another. Morsels of Tatiuwo are used for baiting this fish, and it might be that those found in the stomach were these baits. It is not difficult to understand that this fish finds its sharp teeth and big blind sac useful in taking food.

Family ISTIOPHORIDAE

57. *Makaira mitsukurii* (Jordan et Snyder): Makaziki.

A. Digestive System.

Body elongate, compressed. Mouth large, horizontal. Jaws stretched and pointed; upper jaw almost twice as long as the lower. Small conical teeth closely set in jaws; rudimental teeth on palatines, none on vomer. Buccal cavity large; Plicae palatinae poorly developed. Tongue large, semi-elliptic, thick, not free, somewhat hard but smooth; no melanin chromatophores. Pharyngeal teeth and gill-rakers both absent. Pharynx comparatively large.

Peritoneal cavity moderately large and long, stretches from and beyond the anus; very few melanin chromatophores may be seen scattered on the peritoneum. Oesophagus broad and short, wall thick, folds of mucous membrane longitudinal but not very distinct. Stomach large, fusiform, on account of the

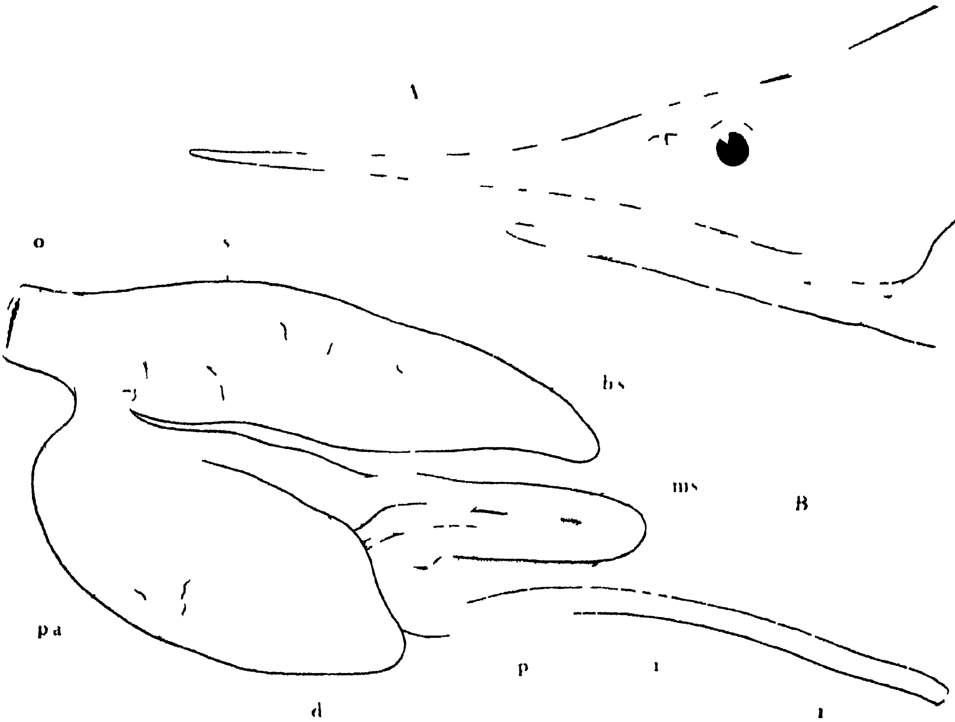


Fig. 80 *Makaira mitsukurii* A Head B Digestive tract

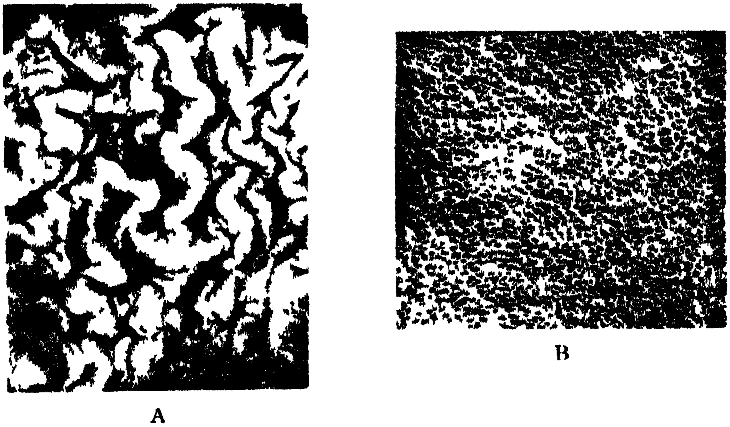


Fig. 81 *Makaira mitsukurii* Folds of mucous membrane A Stomach B Intestine

cardiac and pyloric parts being unusually short and the blind sac a broad and long tube, presents a ┤-shape, wall of stomach thick and distensible; Pars pylorica situated below the stomach, folds of mucous membrane about 15, grooves deep, longitudinal zigzag. Duodenum succeeding the pyloric part at the lower part of the stomach is a very broad tube, being 2 or 3 times broader than any other part of the intestine; differing from the intestine of *Xiphias gladius*, short, form of its winding also different, making only 2 short turnings (N-shape). No difference between the part which corresponds to the rectum and the part which is known as the middle intestine insofar as breadth, etc. is concerned. Wall of intestine thick, the length being ca. 4/9 times the body length, and ca. twice d~a. Folds of the intestinal mucous membrane form short papillae. Pyloric appendages almost the same as those of the tunny and albacore, the bunches of small clusters being covered entirely with a membrane, situated below the stomach, slightly to the right. Mesentery well developed.

Liver situated below the stomach, not very large but rather long, consisting of 2 rather thin lobes. Gall-bladder, a long sac, extends to the first turning of the intestine situated to the right of the stomach. Air-bladder large, rather long, extends to the latter part of the upper portion of the elongated peritoneal cavity.

H. Nakamura (1938), who made a study of the Xiphiiformes fishes in Formosan waters, made a detailed anatomical examination of these fishes, but he made no detailed report on their digestive organs.

B. Feeding Habits.

Contrary to the swordfish which is fished chiefly in winter, this fish is caught in the summer time, which accounts for the fact that the corruptible internal organs, are often removed as soon as the fish is taken from the waters. It was therefore very difficult to obtain the necessary material to study its feeding habits. Consequently, it will perhaps be rather difficult to discuss this subject intelligently and form a definite opinion from the few stomach contents which I was able to examine, but thinking that it will throw some light on the subject and serve as a future guidance, I have decided to give a description of my findings.

Table 16

Stomach contents of *Makaira mitsukurii*

Date	Locality	Number of fish	Body weight (kg)	Body length (cm)	Stomach contents	Remarks
June 20, 1935	35° 32′ N 145° 01′ E	1	ca. 80	150	Suziika (*Symplectoteuthis luminosa*)..2. Tumeika (*Onychoteuthis banksii*) ....1. Sanma (*Cololabis saira*).. 3	Collected by Fuzi Maru
July 24, 1937	—	5	—	110~140	Scombers (?), Squids, Bones of fishes, etc.	Collected from Misaki Fish Market

According to Table 16, it would seem that this fish eats quite an amount of rather large, oceanic fishes. All the fishes which I examined had their stomachs full of food, which it would seem to indicate that this fish belongs to the rather voracious set. An adult skipper, as shown in the photograph,

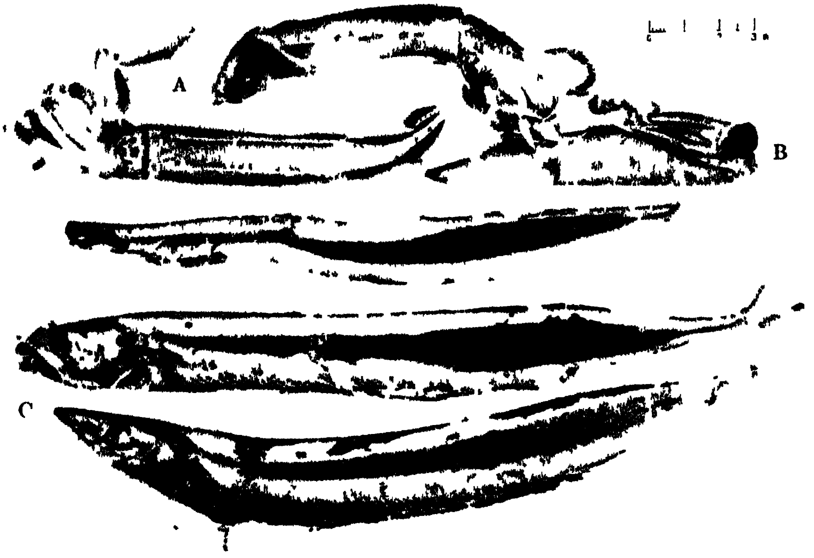


Fig. 82 Stomach contents of *Makaira mitsukurii* A *Symplectoteuthis luminosa* B *Onychoteuthis banksii* C *Cololabis saira*

was found in the stomach of this fish caught off the eastern coast of Bôsô Peninsula in June, which I think is an interesting fact in studying the skipper's habits, especially in connection with its migration.

Family XIPHIIDAE

58. *Xiphias gladius* (Linné): Mekaziki.

A. Digestive system.

Body elongate, compressed. Mouth large, horizontal. Jaws stretched and pointed, upper jaw very long, being over 4 times longer than the lower. No teeth in jaws, none on vomer, palatines, nor pharyngeal bones. Buccal cavity large. Plicae palatinae not developed, smooth, forming net-work. Tongue large, semi-elliptic, thick, not free, somewhat hard, but smooth, no melanin chromatophores. Pharyngeal teeth and gill-rakers both absent. Pharynx comparatively wide.

Peritoneal cavity moderate in size, short, more or less compressed sidewise; few melanin chromatophores scattered on the peritoneum. Oesophagus short and wide, walls thick, mucous membrane of which forming fine obscure longitudinal folds. Stomach large, fusiform. Contrary to the cardiac and pyloric parts being exceptionally short, the blind sac is wide and cylindrical, presents ˥-shape, walls thick and stand stretching. Situated at the lower part of the stomach is the pars pylorica, mucous membrane forming rather deep, zigzag, longitudinal folds. Duodenum at the end of the stomach connects

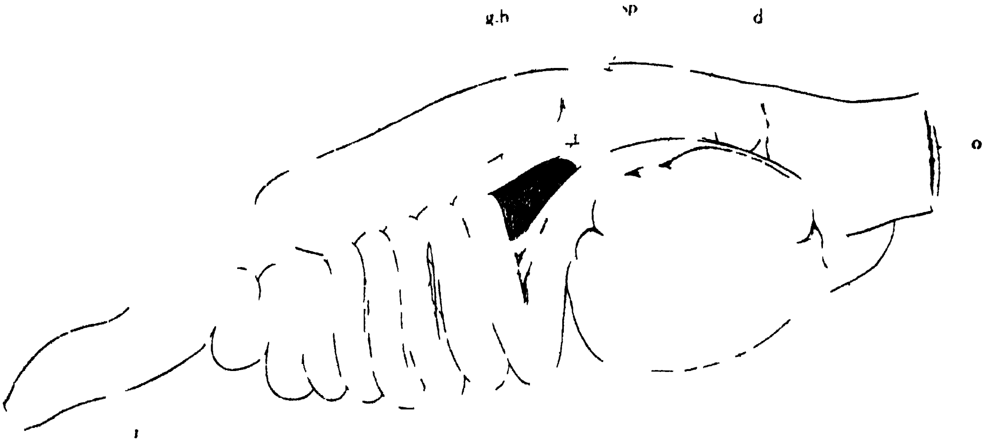


Fig. 83. *Xiphias gladius*

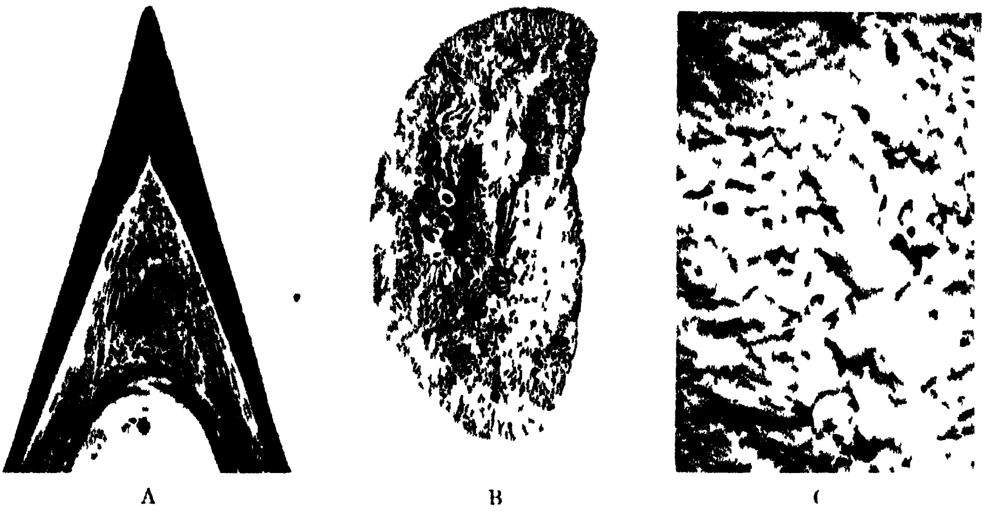


Fig. 84. *Xiphias gladius*. A. Lower jaw. B. Cross section of pyloric appendages. C. Folds of mucous membrane of intestine.

with the pyloric part and, as shown, runs along the pyloric appendages one degree upwards and present a U-shape tube flat where it goes around the upper right of the stomach (not as wide as that of *Makaira mitsukurii*) mucous membrane obscure. Intestine differs quite materially with that of *Makaira mitsukurii* already stated and, as illustrated, presents a zigzag (almost coiling), namely, it makes 15 to 20 short turnings, succeeded to this is the rectum which is the thickest part of any of the intestine. Rectum located right in front of the anal fin and opens to the anus. Wall of intestine thick, but the intestine itself rather narrow, total length of which a little shorter than the body length, about 2.8 in o~a and 3 in d~o; rather long papillae grow closely together on the folds of the mucous membrane of the middle intestine and rectum. Mesentery well developed. Pyloric appendages similar to those of *Makaira*, a mass of small clusters covered entirely with a membrane, the illustration showing the sectional parts. They locate at the lower right of the stomach.

Cuvier (1809) reported that the intestine of this fish was long and had thick walls, and Jacobshagen (1911) said that the stomach was a long round sac with thick wall, and that the intestine made zigzag-like turnings, the wall being thick. Jacobshagen also pointed out the characteristics of the pyloric appendages. H. Nakamura (1938) wrote a little about the intestine of this fish but failed to mention its characteristic winding.

Liver, small, consists of imperfect left and right lobes, rather thick, located in front of the pyloric appendages. Gall-bladder rather large, long sac, the end extending to the middle of the stomach. Ductus choledochus moderately long. Spleen situated between the duodenum and the middle intestine, moderately large, flat somewhat. Air-bladder large, fusiform.

B. Feeding Habits.

This being a cosmopolitan fish, it has had many reports written about its habits. But of its many habits, attention was drawn principally to its feeding habits and the fact that it attacked whale and fishing boats with its stretched jaws. Regarding the latter, as remarked in the previous chapter under "Historical Review", Josselyn (1674), Koelpin (1770–1771), Thompson (1844), Gray (1871), Wilcox (1887), Maclaren (1909), Boulenger (1931), and H. Nakamura (1938), all reported on this, but as this differs somewhat from feeding habits, I am not taking it up here. The feeding habits of this fish have been roughly described hitherto in popular and text-books, but I am inclined to think that the report of Goode (1880) was the first and oldest scientific paper to discuss this subject. He says that he obtained small fishes and squids from the stomachs of *Xiphias gladius* which he had collected at Seaconnet, America, in 1875. According to him, the common food of sword-fish in the western Atlantic Ocean is fishes. As to the manner in which it obtained food, he said that it approached schools of fishes body upstraight, and with its stretched jaws pierced its prey or threw them into the air, only to devour them. Clark (1884) reported that the stomachs of swordfishes collected in the waters of Cape Cod and Gulf of Maine contained squids, skipjacks, dogfish, mackerels and herrings. In a recent book by Walford (1937), he wrote that this fish fed on schooling fishes like mackerels, barracuda, sardines, flying-fish, anchovies, herrings and squids.

I made examinations of the stomach contents of *Xiphias gladius* collected in 3 or more different fishing grounds and found that all of them had eaten animals, mainly fishes, which were to be found in deep-sea where there were rocks and stones. In contrast with the results of various studies by the above mentioned scholars, it would seem that this fish fed on fishes near the surface of the ocean which migrate from place to place, and at the same time

Table 17

Stomach contents of *Xiphias gladius*

Date	Locality	Number of fish	Body weight (kg)	Body length (cm)	Stomach contents	Remarks
Jan. 30, 1936	Unknown	10	—	—	Simagatuwo (*Brama raii*), lantern-fishes, squids, etc.	Collected from Kesennuma Fish-Market
Jan. 25, 1939	35°49′N 141°25′E	1	78.97	178	Itokiki-dara(*Laemonema morosum*) 12 (2.2 kg)	Collected by Sôyô Maru
Feb. 23, 1939	34°16′N 140°04′E	1	95.25	158	Bones of fishes, shrimps	do.

on deep-sea fishes which have their habitat near rocks and stones, which would indicate that the scope wherein it seeked its food, so to speak, was vertically long; in other words, it found its food from the surface to the bottom of the ocean. In 1938, Matsubara announced the Itohiki-dara (*Laemouema morosum*) as a new species. And as shown in the table, 12 of this fish was found in the stomach of 1 swordfish which I examined. The fact that so rare a species which was not hitherto known to us, should be found, and as many as 12 in 1 swordfish, would indicate that the deep-sea fishes make school in the deeper layer.

Family CORYPHAENIDAE

59. *Coryphaena hippurus* (Linne): Siira.

A. Digestive System.

Body elongate, much compressed. Head large, compressed; lower jaw slightly projecting. Mouth large (m-c being ca. 1/3 of head length), directed slightly upwards. Teeth in jaws conical and small. Mouth cavity moderately large, compressed; small teeth on vomer and palatines, and pharyngeal bones. Tongue large, rectangular, thin, free, minute but rather sharp teeth on the surface (Pl. III, Fig. 16). Gill-rakers short (the length being ca. 1/5 of corresponding gill-filaments), tips blunt, coarse, 16 in average number.

Peritoneal cavity compressed; oesophagus rather wide with thick wall, the folds of mucous membrane longitudinal. Stomach large, ˧-shape; blind sac long; the mucous membrane of stomach consists of longitudinal serpentine folds. Intestine short (ca. twice as long as d‿a), winds twice, the wall thick, the mucous membrane consists of rather long papillary processes. No rectum. Pyloric appendages almost the same as those of the tunny, albacore, and swordfish, the bunches of small clusters being covered entirely with a membrane, situated at the left side of the stomach. Mesentery well developed.

Liver large, thick, consisting of 2 lobes, the right lobe larger than the left, hanging over the stomach; gall-bladder very long, stretched to the end of the stomach. No air-bladder.

B. Feeding Habits.

The point of note of this fish is that while it is a migratory fish, it is

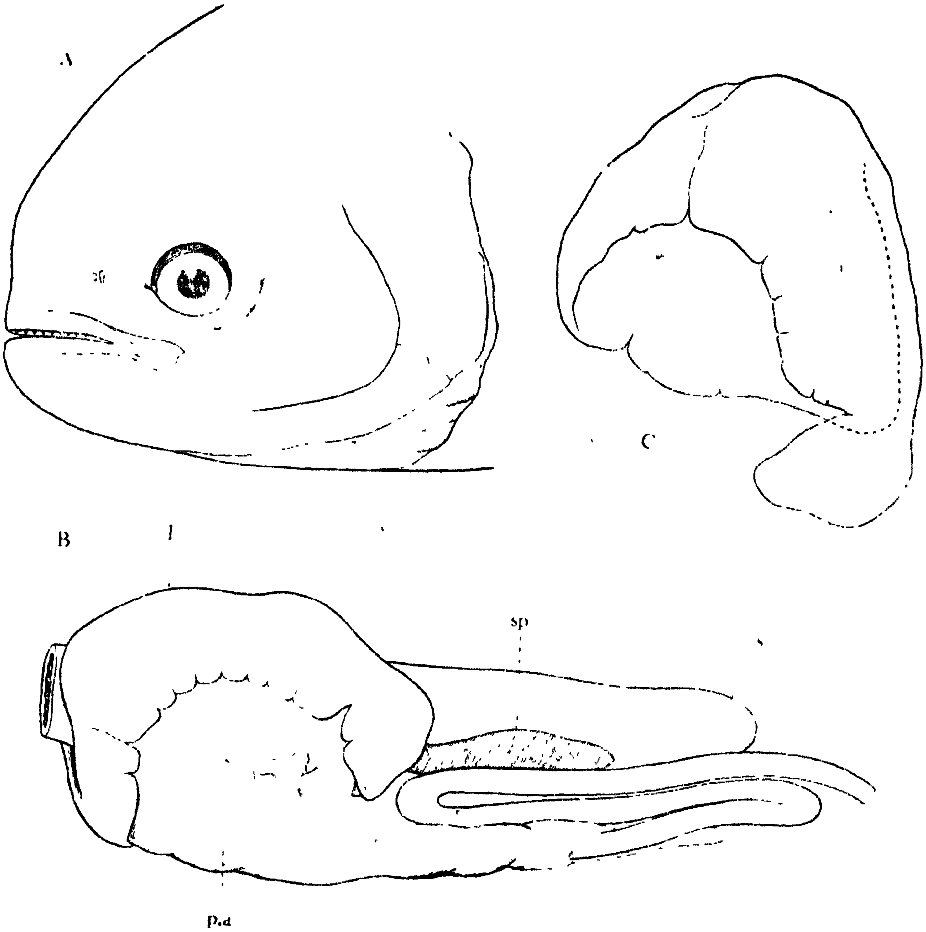
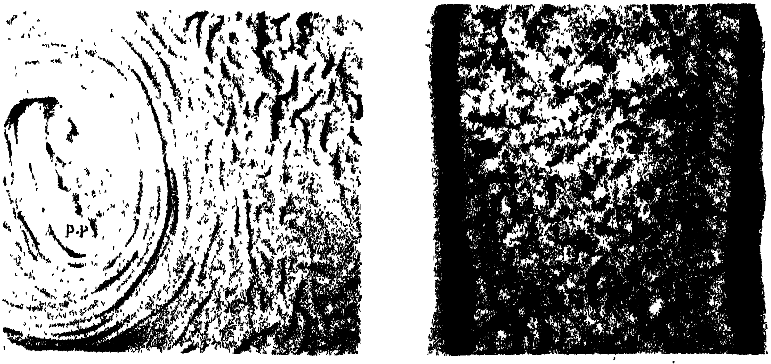


Fig. 85. *Coryphaena hippurus.* A. Head. B. Digestive tract. C. Liver.



A B

Fig. 86. *Coryphaena hippurus.* A. Folds of mucous membrane of stomach. B. The same of intestine.

at the same time a fish that prefers shadowy places. For this reason, in Japan, to catch this fish, we place what we call the "Siira-zuke" (a piece of bamboo work, weaved together, which makes shadowy spots in the water, allowing us to catch the dolphins that gather there) in its pathway.

Table 18

Stomach contents of *Coryphaena hippurus*

Date	Locality	Body length (cm)	Stomach contents
June 19, 1935	Adjacent waters of Smith Island	75	Sardines, cuttle-fishes
,,	,,	78	Sardines, *Lepas* sp.
,,	,,	80	Sardines, *Lepas* sp., cutfle-fishes
,,	,,	80	*Lepas* sp.
,,	,,	84	*Lepas* sp.
,,	,,	90	Sardines, cuttle-fishes
June 27, 1938	31° 47′ N 132° 05′ E	93	Sardines
June 29, 1938	--	105	None
,,	—	120	Sardines, cuttle-fishes
June 7, 1938	Off the coast off Miyazaki Pref.	—	Flying-fish
June 9, 1938	,,	—	None
June 12, 1938	Off the coast of Tosa Pref.	—	Flying-fish

On analyzing the stomach contents of the samples which I found around a floating log while out on one of the bonito fishing boats off the coast of Izu and those which Mr. M. Uda kindly obtained for me from the coast of Miyazaki Prefecture, I found that they were not only carnivorous but very voracious (there were some that had swallowed whole a large flying-fish). At the same time, as is the case with migratory fishes, it very often happens that it does not come in contact with its prey, in which case it feeds on *Lepas* and the like which are found on the logs afloat in the shadows of which it likes to hide itself.

Family BRAMIDAE

60. *Brama raii* (Bloch): Simagatuwo.

A. Digestive System.

Body elongate, compressed, very thin. Mouth moderately large (m-c being ca. 1/2.2, m-b being ca. 1/4.2 of head length), directed very obliquely upward; lower jaw projects very much beyond the upper; jaws armed with 2 rows of somewhat slender, pointed, small teeth, the band being a little broader at the terminal; teeth on vomer and palatines minute; no lip. Buccal cavity small. Palatal mucous membrane black; Plicae palatinae smooth. Tongue large, semi-elliptic, moderately thick, free, black, rather soft and smooth. Pharyngeal teeth rather large, larger than the jaw teeth, closely set on the

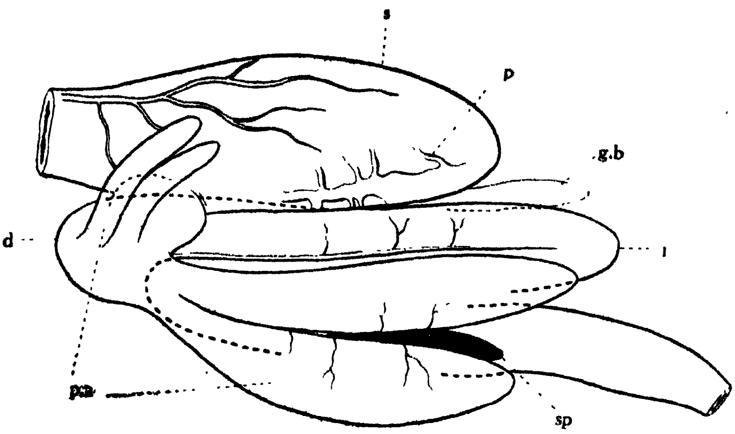


Fig. 87. *Brama raii.*

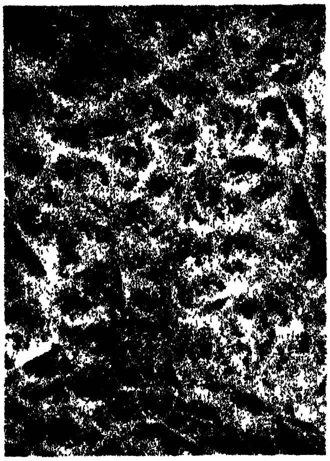


Fig. 88. *Brama raii.* Folds of mucous membrane of intestine.

3 sets of the upper and one set of the lower pharyngeal bones.

Peritoneal cavity diciform, not large; peritoneum silvery. Oesophagus short. Stomach large, ˥-shape; cardiac and pyloric parts short; blind sac large. Cardiac part broad but pyloric part round, narrow, and short; wall thick; folds of mucous membrane longitudinal and papillary. Intestine short (total length being ca. 2.2 times d~a), making 2 turns, wide, wall thick; folds of mucous membrane double net-work; no difference between the duodenum and the rectum, covered with numerous veins; mesentery pretty well developed: anus situated between the ventral and anal fins. Pyloric appendages characteristic, namely, 2 of the 5 appendages very large and long, the remaining 3 small and short.

Liver not large, 2 lobes, left lobe larger than the right, hangs over the oesophagus. Gall-bladder a narrow tube; Ductus choledochus short. Pancreas well developed, located below the stomach, between the pyloric appendages and along the intestine. No air-bladder.

B. Feeding Habits.

As may be seen from the Table 19, *Brama raii* is a real carnivorous fish, having rather voracious habits. And judging from the fact that the stomach contents consist of the fishes such as *Bentenia aesticola* or Cottidae, it would seem that this fish lives usually near rocks in pretty deep waters. I think that it is worth noting that it is frequently attacked by swordfishes and tunnies.

Table 19

Stomach contents of *Brama raii*

Date	Locality	Sex	Body weight (g)	Body length (cm)	Stomach contents	Remarks
May 15, 1935	Off the coast of Kisyû	♀	1175	55.7	Young fishes of Bentenuwo (*Bentenia aesticola*), etc	
”	”	♀	1201	61.4	Indistinct	
”	”	♀	840	36.9	Bones of fishes, shrimps	
Apr. 4, 1939	Unknown	♀	825	37.5	Sculpins (*Cottidae* ..3 (13.1 g)	Collected from Tokyô Fish Market
”	”	♀	925	31.5	Sculpins, etc.	do.
”	”	♂	835	33.0	do.	do.

Family STROMATEIDAE

61. *Psenopsis anomala* (Temminck et Schlegel): Ibodai.

A. Digestive System.

Body rather elongate, compressed. Head short, compressed. Mouth small (m-c being ca. 2/9 and m-b ca. 1/3 of head length), oblique: lower jaw a little longer than the upper. A row of villiform teeth in each jaw; those in the lower somewhat larger than those in the upper jaw. Mouth cavity small; folds of the palatal mucous membrane longitudinal; no teeth on vomer and palatines. Tongue large, rectangular, smooth, free, rich in melanin chromatophores. Upper pharyngeal teeth rather sharp and numerous. Gill-rakers slender (the length being ca. 3/4 of corresponding gill-filaments), tips pointed, flat, coarse, 20 in number of average.

Peritoneal cavity compressed; a few melanin chromatophores scattered on the peritoneum. Oesophagus short, with thick wall. Preceding the stomach is a fore-stomach, peculiar to Stromateidae (these remarks also apply to Pampidae which is described in the next chapter); a kind of a stomach located between the oesophagus and the stomach: spherical and black, with a thick wall, mucous membrane of which chitinous, numerous columnar epithelium. Stomach rather large, ˥-shape, wall moderately thick, consisting of a cardiac part of normal length, a rather long blind sac, and an extremely short pyloric part; mucous membrane 10 to 12 longitudinal folds. Intestine short, as illustrated, winds twice (the length being ca. thrice as long as d~a), wall rather thick, mucous membrane net-work at the beginning, the relief fading as it gets towards the end. Pyloric appendages very peculiar, as shown in the figure, like a pine-cone, the interior of which dividing into several chambers.

Liver medium in size; consisting of a moderately large left lobe and a very small right lobe; gall-bladder rather slender.

B. Feeding Habits.

From 1931 to 1937, as occasion presented, I examined the stomachs of a great number of this fish but on no occasion were there any stomach contents

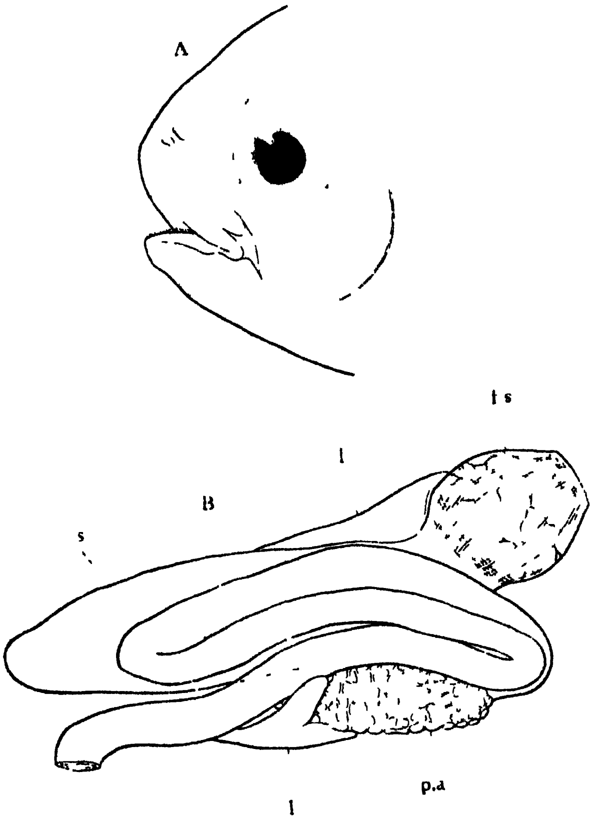


Fig. 89. *Psenopsis anomala* A. Head. B Digestive tract (f.s: fore-stomach).

to be found. There was always a small quantity of gelatine-like substances, but otherwise the stomachs were practically empty. Such being the case, I could not ascertain for certain the chief food of this fish, but judging from its gelatine-like stomach contents and the fact that the construction of its stomach was similar to that of the species which will be discussed in the next chapter, I would contend that jelly-fish was its chief food, as in the case of the following species.

Family PAMPIDAE

62. *Stromateoides argenteus* (Euphrasen): Managatuwo.

A. Digestive System.

Body greatly compressed; snout short; mouth small (m-c being ca. 1/7 and m-b ca. 1/4 of head length). Flat small teeth with rounded tips in each jaw. Mouth cavity small, compressed; no teeth on vomer and palatines. Tongue large, rectangular, free, smooth, and soft, rimmed on both sides; melanin

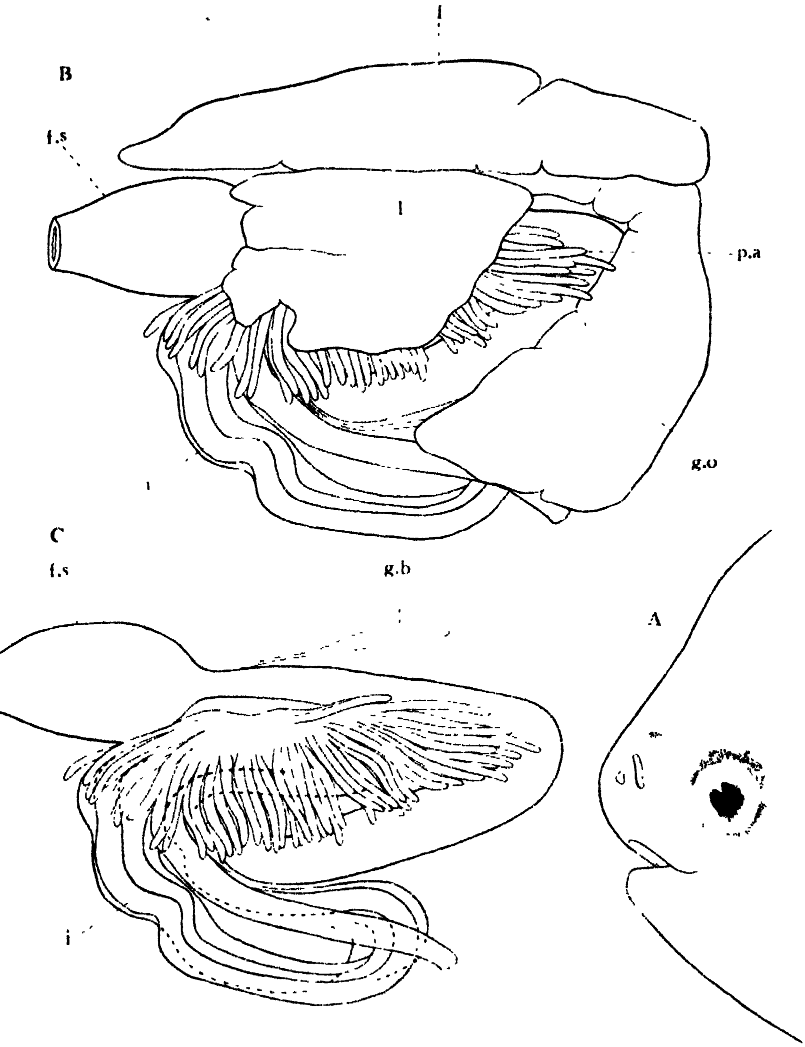


Fig. 90. *Stromateoides argenteus.* A. Head. B., C. Digestive tract.

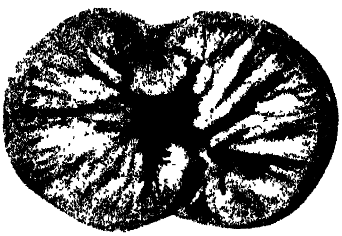


Fig. 91. ***Stromateoides argenteus.*** **Cross section of fore-stomach.**

chromatophores not many. Pharyngeal teeth minute. Gill-rakers moderately long (the length being ca. 1/5 of corresponding gill-filaments), tips pointed, curved, 19 to 20 in number, process on a gill-raker few.

Peritoneal cavity compressed; melanin chromatophores on the peritoneum very few. Oesophagus short but broad, wall thick. Succeeding the oesophagus a black fore-stomach situated as in the foregoing species, the form and mucous membrane of which also being almost alike. The stomach of the foregoing species was ˥-shape, while the present one is a perfect U; mucous membrane with 6 to 7 longitudinal folds. Contrary to the very short intestine of the above species, the present one is extremely long (about 7 to 10 times d~a). It is to be noted that the intestine of this fish differs individually, namely, some broad and short, and some narrow and long. Wall of the intestine thinner than that of the stomach; winds in the form of the letter 8; mucous membrane longitudinal serpentine folds. No clear distinction between the middle intestine and the rectum, the anus opening just in front of the anal fin. Pyloric appendages long and rather narrow, about 600 in number, the bunch of appendages being located mainly on the left of the stomach.

Liver large and thick, situated on the upper left of the alimentary canal; gall-bladder more or less elongate, located on the right side of the fore-stomach; bile duct opening to the beginning part of the duodenum. Pancreas scattered collectively near the liver and the pyloric appendages.

B. Feeding Habits.

As this is a very expensive fish, I obtained only the guts of this fish from a fishmonger and studied them. (In studying its digestive system, needless to say that I obtained several complete ones). It will be seen from the table that in each case, there were hardly any contents in the stomach, the same as in the case of the foregoing species, although there were some gelatinous substances and tentacles of medusa, which would indicate that the food of this fish specializes in medusa.

Table 20

Stomach contents of *Stromateoides argenteus*

Date	Locality	Number of fish	Av. body length (cm)	Stomach contents
Feb. 13, 1933	Tokyô Fish Market	10	20.7	None..10/10
May 24, 1934	,,	4	22.0	Tentacles of medusa..1/4, none..3/4
June 3, 1835	,,	15	23.1	Tentacles of medusa..5/15, gelatinous substances..7/15, none. 3/15
Aug. 12, 1939	Yobimatu, Okayama Pref.	7	25.4	Gelatinous substances..4/7, none..3/7

Family CARANGIDAE

63. *Trachurus japonicus* (Temminck et Schlegel): Maazi.

A. Digestive System.

Body elongate, compressed. Head moderately long; mouth medium in size (m-c being ca. 5/13 and m-b ca. 1/5 of head length); lower jaw trifly longer than the upper; upper jaw protrusible. Teeth in jaws very fine. Mouth cavity moderately large; palatal mucous membrane longitudinal folds. Tongue tolerably large, rectangular, thin, free anteriorly, rich in melanin chromatophores, in the middle partly armed with a band of very minute teeth. Tips of the pharyngeal teeth rounded, growing closely together on 1 set of the lower

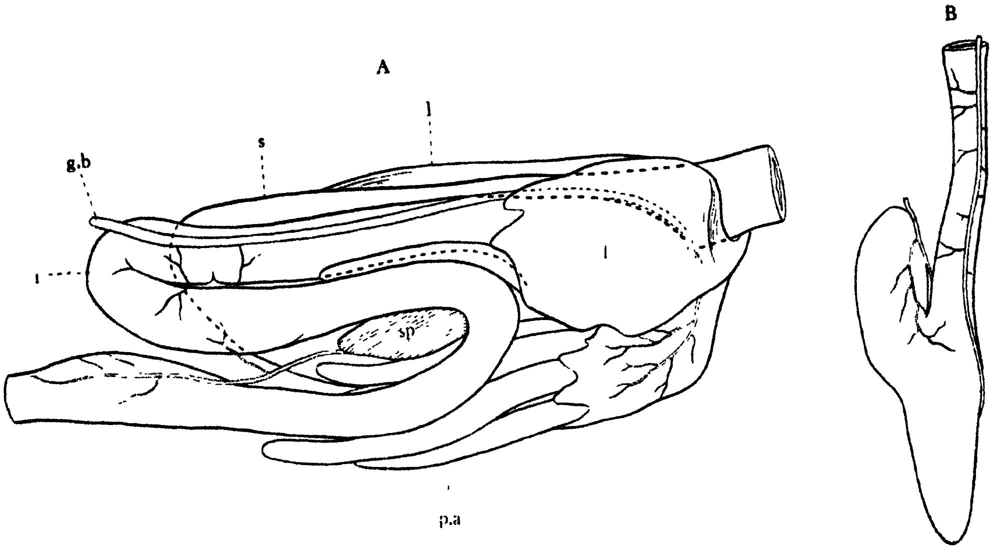


Fig. 92. *Trachurus japonicus* A. Digestive tract. B. Stomach.

pharyngeal bones and the 3 sets of the upper pharyngeal bones. Gill-rakers slender (the length being a little shorter than corresponding gill-filaments), closely set, tips pointed, 50 to 55 in number, process on a gill-raker numerous.

Peritoneal cavity rather large: peritoneum black. Oesophagus rather narrow, folds of the mucous membrane longitudinal. Stomach ⊣-shape, medium in size, wall rather thick; mucous membranes of the cardiac part and blind sac consist of about 12 longitudinal serpentine folds, the pyloric part having the thickest wall. Intestine rather short (the length being ca. thrice as long as d~a), making 2 windings, forms the letter N or S, broad but the wall very thin, mucous membrane consists of longitudinal folds of papillary processes. Pyloric appendages long, 15 in number (4 of which situated on the left side of the stomach, the remainder on the right).

Fig. 93. *Trachurus japonicus.* Folds of intestinal mucous membrane.

Liver medium in size and in thickness, consists of 2 lobes, situated on the right and lower part of the stomach; gall-bladder long and slender. Air-bladder rather large and fusiform.

Jacobshagen (1911) anatomized the digestive tract of *Caranx trachurus* and reported that the number of the pyloric appendages of this fish was 12

(13, according to Meckel). Wakiya (1924) who studied the carangoid fishes of Japan, made no mention of the internal organs of this fish in his report.

B. Feeding Habits.

This is a coastal fish and found generally in the middle stratum of the sea where it is about 300 feet deep, sandy and rocky at the bottom. During daytime it dives deep but at night, especially when it is allured by a light, it comes up near the surface.

In June 1933, I made a rough examination of the stomach contents of 47 horse-mackerels, about 8 cm in body length, which Mr. I. Gensyô had collected by a fish-gathering lamp in Koaziro Bay, Kanagawa Prefecture, and found that everyone of them had stuffed its stomach with larval fishes and copepods.

64. *Decapterus muroadsi* (Temminck et Schlegel): Muroazi.

A. Digestive System.

Body elongate, scarcely compressed; snout rather long. Mouth moderately large (m-c being ca. 1/4 and m-b ca. 1/6 of head length); lower jaw a little longer than the upper, the latter being protrusible. A series of minute, conical teeth in each jaw; very minute teeth on vomer and palatines. Tongue, medium in size, triangular, thin, free, armed with very minute teeth, melanin chromatophores scattered on the surface. Pharyngeal teeth trifly larger than the above-mentioned species. Gill-rakers long (the length being ca. 4/5 of corresponding gill-filaments), flat, tips pointed, closely set, 46 to 48 in number.

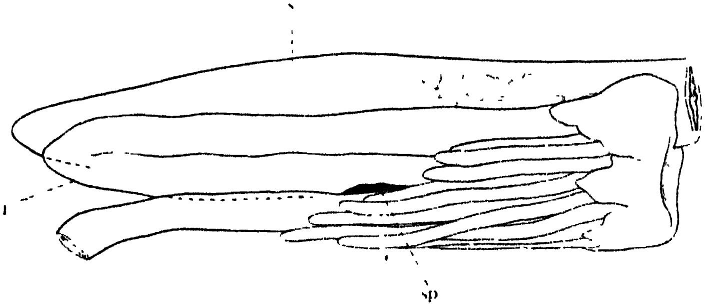


Fig. 94. *Decapterus muroadsi.*

Peritoneal cavity rather large, elongated; peritoneum black. Stomach ┤-shape; blind sac long, the cardiac and pyloric parts being very short; wall thick; folds of the mucous membrane longitudinal. Intestine rather short (the length being thrice as long as d⁓a), winds twice, mucous membrane consisting of longitudinal folds of papillary processes. Pyloric appendages long, 18 to 24 in number.

Liver small, poly-lobed, located below the duodenum.

B. Feeding Habits.

On June 11, 1933, when I examined 50 of these stomachs obtained from a fishmonger, I found that most of them had eaten a stomachful of larval fishes (*Seriola*?). I am told that this fish is more voracious and carnivorous in its feeding habits than those of the above-mentioned species.

65. ***Alectis ciliaris*** (Bloch): Itohikiazi.

A. Digestive System.

Width of body nearly equal to its length, body very much compressed; anterior 7 rays of soft dorsal and 5 of anal exceedingly produced, their first rays being much longer than twice the length of the body. Mouth small (m-c being ca. 1/4 of head length), directed slightly upwards. Teeth in jaws very minute, growing in bands. Mouth cavity large, compressed; vomer and palatines armed with villiform teeth; tongue small, triangular, rather thin, lacking in melanin chromatophores, armed with villiform teeth. Pharyngeal teeth small but stout. Gill-rakers rather long (the length being ca. 2/3 of corresponding gill-filaments), flat, closely set, 20 in number of average.

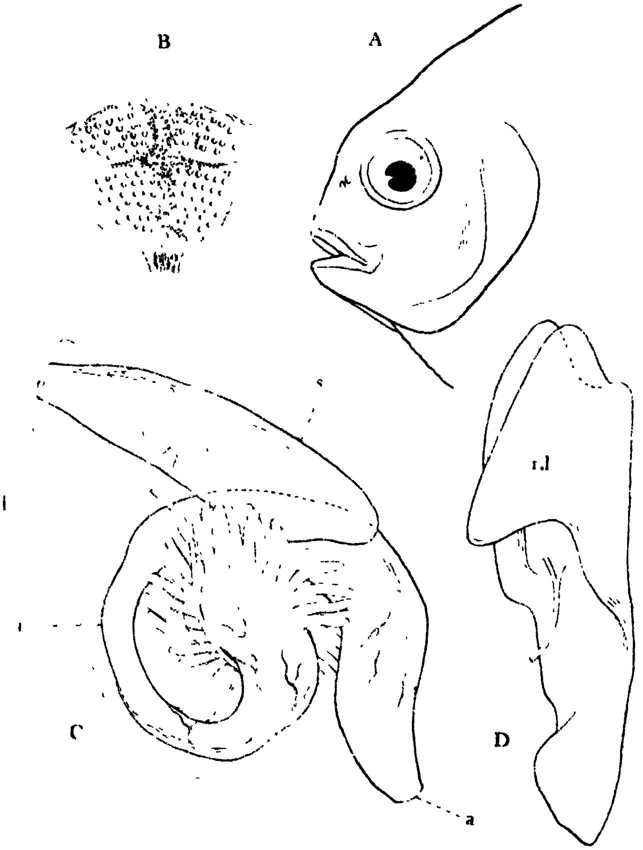


Fig. 95. *Alectis ciliaris*. A. Head. B. Pharyngeal teeth. C. Digestive tract. D. Liver.

Peritoneal cavity small, compressed sidewise but diciform; peritoneum rich in melanin chromatophores. Stomach rather large, consisting of a long cardiac part, a short blind sac and a short pyloric part, wall rather thick; 15 to 16 longitudinal folds, between which are numerous short papillae. Intestine short, wall rather thin, winding once, draws a circle from the duodenum to the anus; mucous membrane longitudinal folds with papillary processes. Pyloric appendages short, about 30 in number, spreading out in all directions. Mesentery well developed inside the circle which the intestine itself draws; blood vessels and pancreas are well distributed on this part.

Liver large, consists of 2 lobes, the left being much larger than the right, and covers the cardiac part of the stomach and the middle part of the intestine diagonally; gall-bladder long. Air-bladder large and long.

B. Feeding Habits.

This is a rare species and cannot be found often. But through the courtesy of Prof. A. Miyamoto and the assistance of Mr. H. Yamamoto, I was able to obtain the results of study shown in the table.

Table 21

Stomach contents of *Alectis ciliaris*

Date	Locality	Number of fish	Body length (cm)	Stomach contents
Aug. 3, 1931	Mito, Sizuoka Pref.	10	7.2～8.0	Larval fishes, *Thysanoessa gregaria*, etc.
Sept., 1934	Katuura, Tiba Pref.	5	9.7～10.4	Eggs of cuttle-fishes, etc.

66. *Seriola quinqueradiata* (Temminck et Schlegel): Buri.

A. Digestive System.

Body elongate, compressed. Snout pointed, conical. Mouth medium in size (m-c being ca. 4/13 of head length). A band of minute conical teeth in each jaw (Pl. I, Fig. 1). Mouth cavity rather large; vomer and palatines armed with minute teeth; tongue medium in size, triangular, free, tip blunt, thin anteriorly, lacking in melanin chromatophores, teeth on the surface rudimentary. Pharyngeal teeth rather small and tips blunt, closely set on the 3 sets of the upper and 1 set of the lower pharyngeal bones. Gill-rakers long (the length being less than 2/3 of corresponding gill-filaments), rather broad but flat, tips blunt, closely set, 28 to 32 in number, process on a gill-raker numerous (Pl. IV, Fig. 10).

Peritoneal cavity rather elongate; oesophagus broad with thick wall, folds of the mucous membrane longitudinal; stomach a long sac, ┐-shape, wall thick; blind sac long and the pyloric part very short, oval; folds of the mucous membranes of the cardiac part and blind sac longitudinal, while those of the pyloric part net-work. Development of blood vessels conspicuous on the stomach. Intestine moderately wide, wall thick, winds twice as shown in the figure, the length being about thrice as long as d～a; mucous membrane furnished with numerous papillary processes like those of the dolphin(P l. XI, Fig. 24).. Pyloric appendages moderately long, 250 to 300 in number.

Liver rather small, 2 lobes, covering the oesophagus, cardiac part of the stomach, and the anterior part of the pyloric appendages; gall-bladder a long sack, stretching along the intestine.

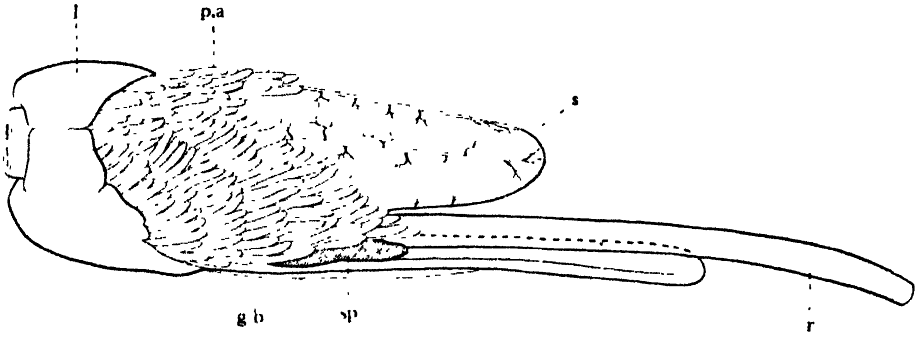


Fig. 96. *Seriola quinqueradiata.*

B. Feeding Habits.

Matuno (1918) found in the stomachs of his material, collected off the coast of Kôti Prefecture, in addition to sardines and mackerels, *Acanthocepola* which live at the bottom of a depth of over 500 feet. Otiai (1919, 1923) reported that according to the results he had obtained from his material collected off the coast of Tango, Kyôto Prefecture, they had eaten sardines, horse-mackerels, bonitos, mackerels, flat-fishes, cuttle-fishes, etc. and many were with empty stomachs. The Kanagawaken Fisheries Experimental Station (1922) found, after an examination of 24 of this species, approximately 1 meter long, that Clupeoid fishes constituted its main diet. Itizima (1923) experimented with material collected from Toyama Bay, and found sardines, mackerels, cuttle-fishes, etc. as its stomach contents. According to Miura (1936) who made a thorough study of oecology with material obtained off the coast of Sizuoka Prefecture, sardines and cuttle-fishes constituted the chief food of this fish even at its young stage, viz., "Inada". It will be seen from the various studies mentioned above that this fish feeds chiefly on fishes near the surface. In fact, it migrates from coast to coast in pursuit of its prey. A friend of mine, fisherman H. Yamamoto, told me that it was not rare that a school of sardines came swarming into the bay driven by this fish.

67. *Seriola aureovittata* (Temminck et Schlegel): Hiramasa.

There is not much difference in the digestive system of this fish and that of the above species, except that the gill-rakers of the present species are a little less, numbering 20 to 21, and that the pyloric appendages are slightly broader, the number being 1/7 of the foregoing species, i. e., about 40.

68. *Seriola purpurascens* (Temminck et Schlegel): Kanpati.

The points of difference in the digestive system between that of *S. quinqueradiata* are that the gill-rakers of the present species number 16 to 20, while the pyloric appendages number about 60.

Cuvier and Valenciennes point out in their "Histoire naturelle des poissons", Vol. 3, that the number of pyloric appendages of the Genus *Seriola* differs according to the species, taking *S. dumerili* and *S. rivoliana* for their example.

Family LEIOGNATHIDAE

69. *Leiognathus nuchalis* (Temminck et Schlegel): Hiiragi.

A. Digestive System.

Body elliptic, very much compressed. Mouth terminal, small (m-c being ca. 1/5 and m-b ca. 1/4 of head length); jaws of equal length; premaxillary, as illustrated, can be moved backwards and forwards with a rather large range, enabling the mouth to protract and retract freely. A species with such a protrusible mouth is rare and is an item worthy of note insofar as the feeding habits are concerned. Jaw teeth villiform, a row in each jaw. Mouth cavity small; no teeth on vomer and palatines; tongue medium in size, rather narrow rectangular, soft, not free, no teeth and melanin chromatophores on the surface. Pharyngeal teeth small but strong and numerous, good enough to perform the work of grinding food. Gill-rakers moderately long (the length being trifly shorter than corresponding gill-filaments), rounded, soft, tips pointed grow apart, 22 to 23 in number, process on each gill-raker abundant.

Peritoneal cavity very much compressed; melanin chromatophores rather densely distributed on peritoneum. Oesophagus rather long. Stomach a rather broad and rounded tube, no pyloric part, nor blind sac, wall thick, mucous membrane, short papillary processes constituting indistinct longitudinal folds, a valve divides the stomach and intestine. Intestine long (the length being ca. 6 times d⁀a), coils up forming a triangle, wall thick, mucous membrane about 15 distinct longitudinal zigzag folds. Mesentery well developed. Pyloric appendages short, 2 in number.

Liver large, 1 lobe, located on the left side of the digestive organs. Gall-bladder rather large, situated near the third turning of the intestine. Pancreas well distributed along the mesentery. Spleen located to the right of the stomach. Air-bladder large.

B. Feeding Habits.

When I examined the stomach contents of 37 samples (ranging in body length from 9 to 9.8 cm) collected at Miho, Sizuoka Prefecture, on August 1, 1931 and 14 samples (10.2 cm in average) at Kituki, Ôita Prefecture, on June 27, 1936, the first lot had eaten bottom animals consisting primarily of Isopada and clam-worms, while the latter had fed on Amphipoda, fragments of shells, and sea-weeds. From my assumption, it would seem that this fish makes good use of its peculiar protrusile mouth to take the small animal which live principally at muddy bottoms and among sea-weeds.

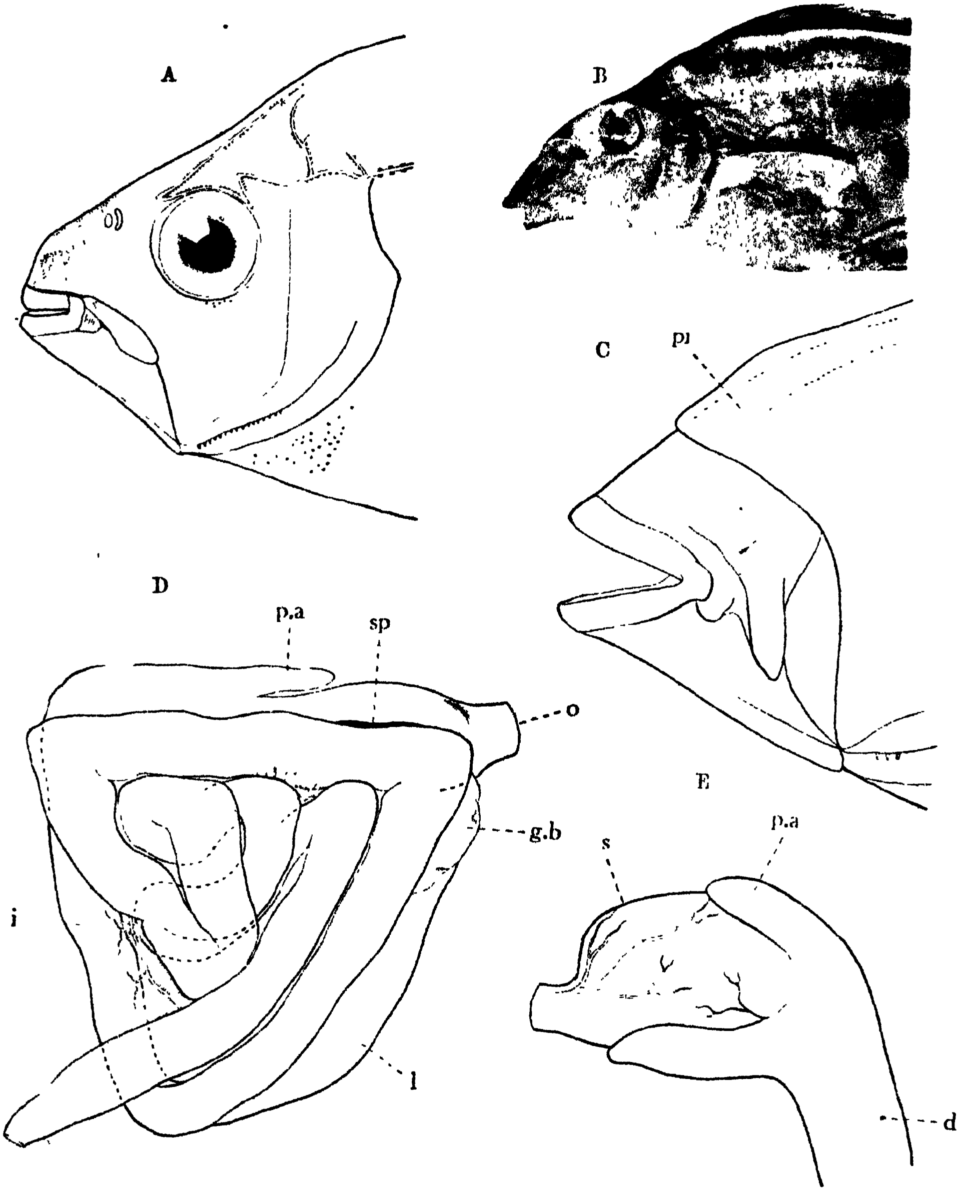


Fig. 97. *Leiognathus nuchalis.* A. Head. B. Protracted mouth. C. Construction of protrusile mouth. D. Digestive tract. E. Stomach and pyloric appendages.

Family TRICHODONTIDAE

70. *Arctoscopus japonicus* (Steindachner): Hatahata.

A. Digestive System.

Body elongate, much compressed. Mouth obliquely upwards, rather large (m-c being ca. 1/3, m-b ca. 1/6 of head length). A row of small conical teeth on each jaw. Mouth cavity compressed sidewise; minute teeth on palatines, but none on vomer. Tongue trianguloid, rather large, free anteriorly, thick, a few melanin chromatophores scattered on the surface. Rows of bluntly pointed teeth on pharyngeal bones. Gill-rakers long (a little shorter than corresponding gill-filaments), tips pointed, flat, closely set, 20 in average number, processes numerous.

Peritoneal cavity medium in size; a few melanin chromatophores scattered in the peritoneum. Oesophagus short; stomach ˥-shape, blind sac large and spherical. The mucous membrane of stomach consists of 7 to 8 longitudinal serpentine folds, and there are net-work folds between them. Intestine not long (the length being ca. 3.5 times d~a), curves once, and bends twice, wall thin, the mucous membrane consists of slender longitudinal folds. Anus opens just in front of the anal fin. Pyloric appendages broad and long, 7 in number.

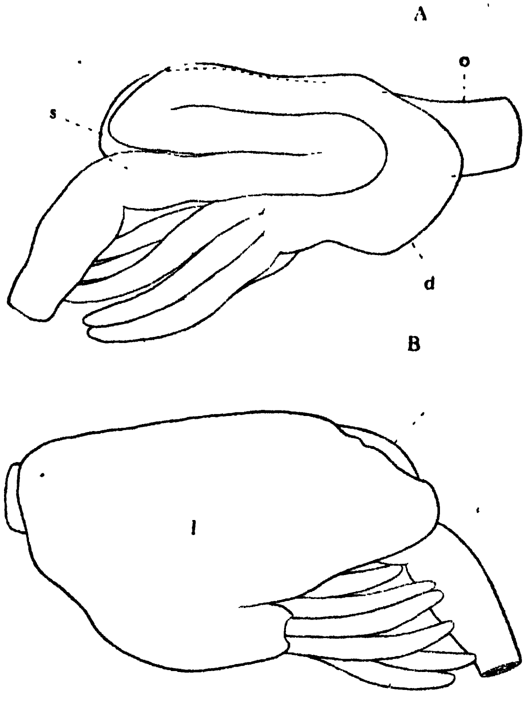


Fig. 98. Digestive organs of *Arctoscopus japonicus*. A. Right side view. B. Left side view.

Liver large, 1 lobe, located on the left side of stomach, thin. Gall-bladder spherical, medium in size.

B. Feeding Habits.

I examined the stomach contents of 10 fishes which were obtained at the Tokyo Fish Market, on Feb. 7, 1937. The stomachs of almost all fishes were filled with small fishes or Schizopoda.

Family OPLEGNATHIDAE

71. *Oplegnathus fasciatus* (Temminck et Schlegel): Isidai.

A. Digestive System.

Body elongate, rather compressed. Mouth medium in size (m-c being a little longer than 1/4 of head length). The upper and lower jaws project

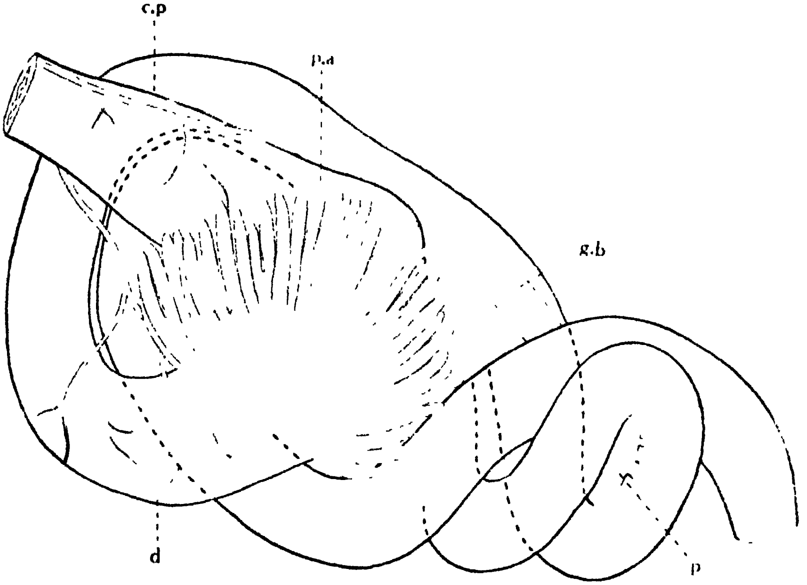


Fig. 99. *Oplegnathus fasciatus.*

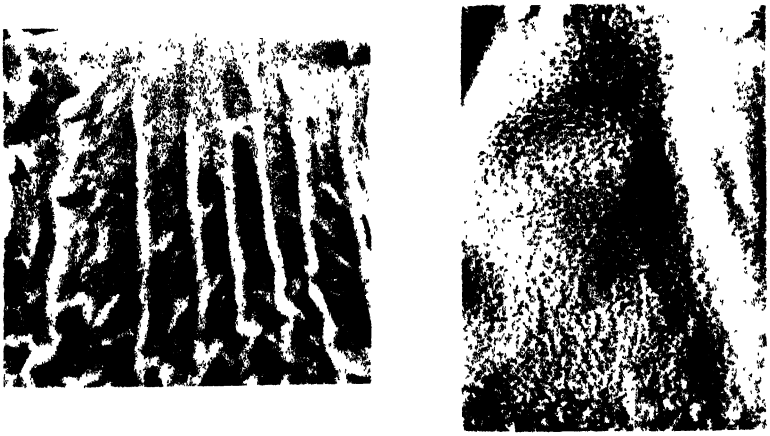


Fig. 100. *Oplegnathus fasciatus.* A. Folds of mucous membrane of stomach. B. The same of intestine.

slightly beyond the lips on account of the dense layers of teeth on the premaxillary and the dentary. The teeth of this fish are similar to those of the parrot-fish and a good example of polyphyodont (Pl. I, Fig. 8). In this connection, I would strongly recommend reference to Hiyama's (1934) report. Mouth cavity moderately large; tongue semi-circular, free anteriorly, soft and smooth, rich in melanin chromatophores. Pharyngeal teeth small and conical. Gill-rakers long (the length being ca. 2/3 of corresponding gill-filaments), flat, tips pointed, 20 in number of average.

Peritoneal cavity large; no melanin chromatophores on the peritoneum. Stomach small, V-shape, the blind sac being very small. Wall of the stomach rather thick, mucous membrane consisting of 8 longitudinal parallel folds, between which are some transversal folds as shown in the photograph. Intestine rather long (the length being ca. 6 times d~a), peculiarly twisted, rather wide, wall moderately thick, mucous membrane consisting of small but numerous papillary process. Pyloric appendages slender, branched, about 50 in number.

Liver medium in size, thin, consisting of a large left lobe and a small right lobe, about 1/70 of the body weight. Gall-bladder a long sac, stretching along the right side of the intestine from the right of the stomach. Pancreas between the winding of the intestine very well developed.

B. Feeding Habits.

According to Uchida (1926) and Hiyama (1934) who studied the life history of this fish, until this fish is about 30 mm in body length, it gathers around floating algae and feeds on the plankton, such as Copepoda, but after that, it leaves its former abode and swims about in the middle layer of the sea and feeds upon Copepoda and Amphipoda and gradually gathers around rocks. When it is more than 100 mm long,' it becomes omnivorous in its feeding habits, and when it is more than 150 mm, it hides behind rocks and takes hard food, such as *Balanus* and sea-urchins. It was pointed out by Hiyama that with these changes in its feeding habits, the teeth also underwent a great change, and I pointed out the interesting connection between the feeding habits of this fish and the development of its digestive tract (1935).

72. *Oplegnathus punctatus* (Temminck et Schlegel): Isigakidai.

Contrary to the striped body of the above mentioned species, especially at its young stage, the present species is dotted, which is the striking difference between these 2 species. There is, however, practically no difference in their digestive system and feeding habits.

Family MULLIDAE

73. *Upeneus bensasi* (Temminck et Schlegel): Himezi.

A. Digestive System.

Body elongate, compressed. Head rather large, snout more or less pointed. A pair of barbels just behind chin. Regarding to the barbel of this fish, Satô (1937) reported that it was formed of 2 layers, viz. epidermis and dermis, and among the epidermis cells, flask shaped cutaneous taste buds were

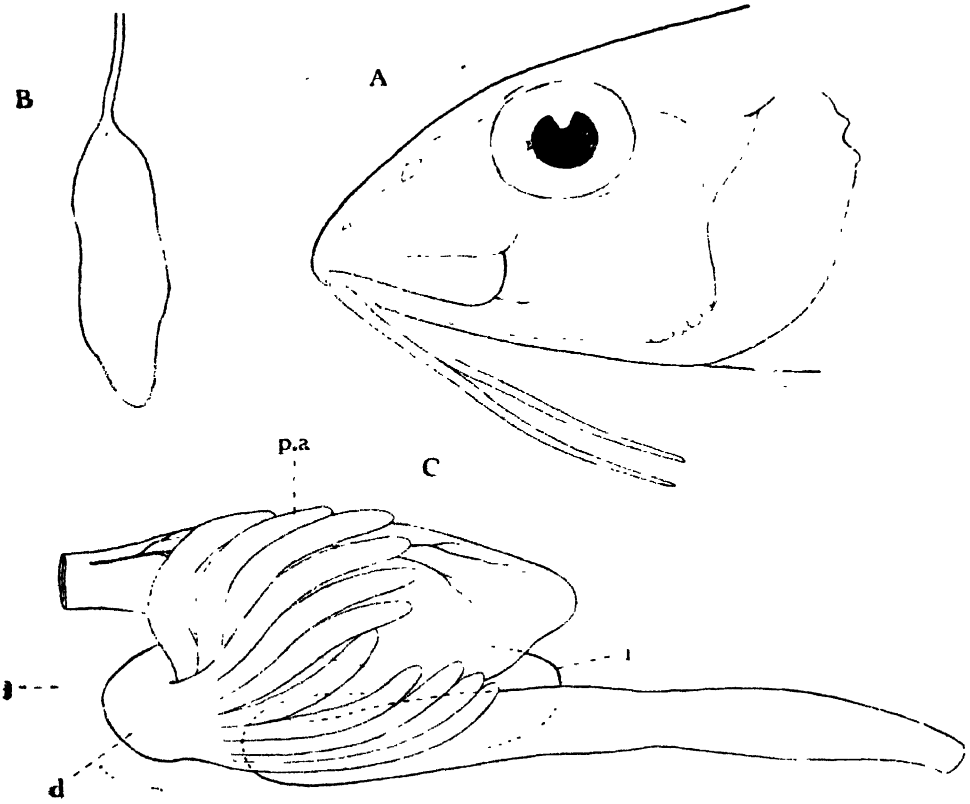


Fig. 101. *Upeneus bensasi.* A. Head. B. Gall-bladder. C. Digestive tract.

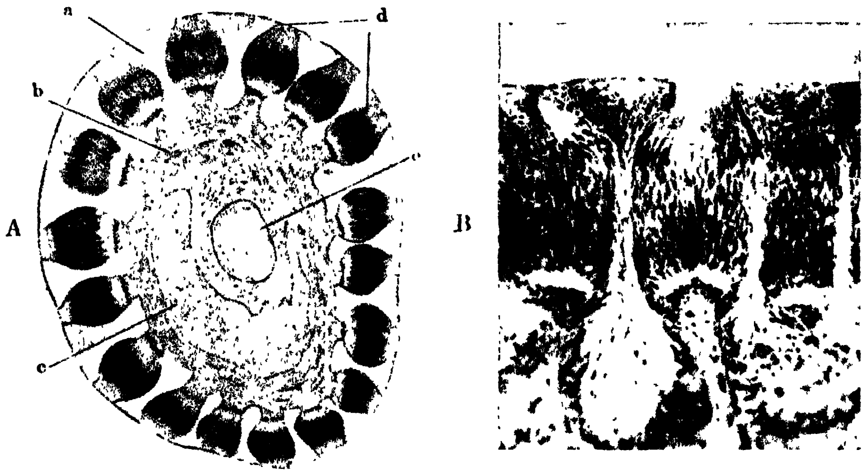


Fig. 102. *Upeneus bensasi.* A. Cross section of barbel. ×100. a. Epidermis; b. Dermis; c. Cartilage; d. Cuteneous taste buds; e. Bundles of nerve fibers. B. Transection through cutaneous taste buds which are imbedded among epidermal cells. ×300. (After Satô).

imbedded numerously, and the most parts of the dermis were occupied by a large number of the bundles of the myelinated nerve fibres. Mouth large (m-c being ca. 1/3, m-b ca. 2/7 of head length), lower jaw included; irregularly 2-rowed minute conical teeth grow in jaws; the teeth on the vomer and palatines rudimentary. Buccal cavity rather small; tongue circular, small, not free, the mucous membrane consists of the folds like the finger-lines, no melanin chromatophores. Small conical teeth grow coarsely on the pharyngeal bones. Gill-rakers moderately long (ca. 4/5 of corresponding gill-filaments), flattened and pointed, coarsely grown, 15–17 in number.

Peritoneal cavity medium in size; peritoneum black. Oesophagus moderately long and wide, the wall thick. Stomach V-shape (cardiac part and pyloric part both long but blind sac degenerated); the mucous membrane of the cardiac part assumes 6–7 of longitudinal folds, while that of pyloric part consists of papillary processes. Intestine rather long (the length being ca. twice as long as d~a), winds thrice, the wall thin, the mucous membrane consists of vein-like folds; rectum broader than the middle intestine. Pyloric appendages long and wide, 11–14 in number.

Liver rather large, thick, consisting of 2 lobes (the right being larger than the left), located below the anterior part of stomach. Gall-bladder rather long, medium in size; bile duct long. Air-bladder large.

B. Feeding Habits.

It will be seen from the following table that this fish feeds chiefly on the bottom living creatures such as the shrimps, clam-worms or amphipods, and it scarcely takes food during its spawning season.

Table 22

Stomach contents of *Upeneus bensasi*

Date	Locality	Number of fish	Body length (cm)	♂:♀	Gonad	Stomach contents	Remark
June 24, 1935	Simizu, Sizuoka Pref.	5	8.8~10.1	3: 2	half-ripe	*Crangon*, Amphipoda	
June 17, 1936	Ogôri, Yamaguti Pref.	20	8.5~12.0	4:16	ripe	None	
May 8, 1937	Aziro, Sizuoka Pref.	3	–	—	unripe	*Crago*, *Nereis*, etc.	Collected by Mr. S. Miyauti

Family CEPOLIDAE

74. *Acanthocepola krusenterni* (Temminck et Schlegel): Akatati.

I observed the construction of the digestive system and the contents of stomach of the fish, weighing 67 g; the length measuring 30.9 cm, which I collected from the adjacent waters of Tomo, Hirosima Pref. on March 23, 1936.

A. Digestive System

Body very long, very much compressed. Head small, compressed; mouth large (m-c being ca. 2/5, m-b ca. 1/3 of head length), slightly oblique upwards;

teeth in a single wide-set row in each jaw, rather long and canine-like, tips blunt. Mouth cavity small, compressed; no teeth on vomer and palatines. Tongue moderately large, triangular, free, thick, smooth, no melanin chromatophores. No pharyngeal teeth. Gill-rakers long (a little longer than corresponding gill-filaments), slender, coarsely grown, 36 in number.

Peritoneal cavity very small in comparison with the body; no melanin chromatophores in the peritoneum. Oesophagus short. Stomach rather large V-shape, cardiac part twice as long as pyloric part, wall thick, the folds of mucous membrane longitudinal. Intestine short (the length being ca. twice as long as d~a), duodenum curves U-shape and middle intestine bends twice. The wall of intestine rather thick, the mucous membrane consists of longitudinal zigzag folds; there is a valve between the middle intestine and the rectum. Pyloric appendages short, 7 in number.

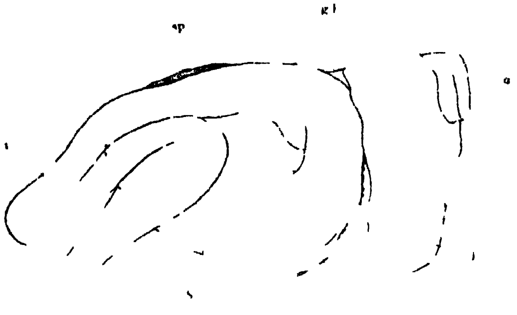


Fig 103 *Acanthocepola krusensterni*

Liver consists of 2 lobes (the left one being larger than the right), located below the cardiac part of stomach. Gall bladder ellipsoid, medium in size. Air-bladder long, the wall thick,

B. Feeding Habits.

This fish seems to be voracious and carnivorous: the fish which I examined had taken fully small shrimps.

Family BRANCHIOSTEGIDAE

75. *Branchiostegus japonicus* (Houttuyn): Akaamadai.

A. Digestive System.

Body elongate, compressed. Mouth medium in size (m-e being ca. 1/3, m-b ca. 2/5 of head length), directed obliquely upwards; upper jaw longer than the lower. Small canine teeth in a band in each jaw. Mouth cavity moderate; folds of palatal mucous membrane longitudinal; no teeth on vomer and palatines. Tongue large, triangular, not free, mucous membrane covering the tongue assumes longitudinal folds, no teeth and melanin chromatophores on the surface. Teeth which grown on 3 sets of the upper pharyngeal bones rather large and sharp. Gill-rakers short (the length being ca. 1/3 of corresponding gill-filaments), tips pointed, flat, coarsely grown, 21 to 22, a few processes on each gill-raker (Pl. IV, Fig. 8).

Peritoneal cavity rather small, compressed. Oesophagus short and wide, wall thick, mucous membrane consists of about 20 longitudinal folds. Stomach small, curved I-shape (pyloric part almost degenerated), wall thick, mucous membrane consists of longitudinal parallel folds (Pl. VI, Fig. 4); cardiac part wide and blind sac narrow. Stomach clearly separated from duodenum by a valve inside. Intestine moderately long (the length being ca. thrice as long as d∼a), winds several times as shown in the figure (a variation of N-form winding), the anterior part of intestine (or duodenum) wide, while the middle part (middle intestine) rather narrow. Rectum succeeds to middle intestine through double valves at their boundary. Folds of mucous membrane of the intestine very short papillae irregularly arranged, somewhat like the surface of a towel (Pl. XII, Fig. 27), while those of the rectum longitudinal. Wall of rectum thick. Pyloric appendages 2, but they are so short and small that we sometimes overlook them carelessly.

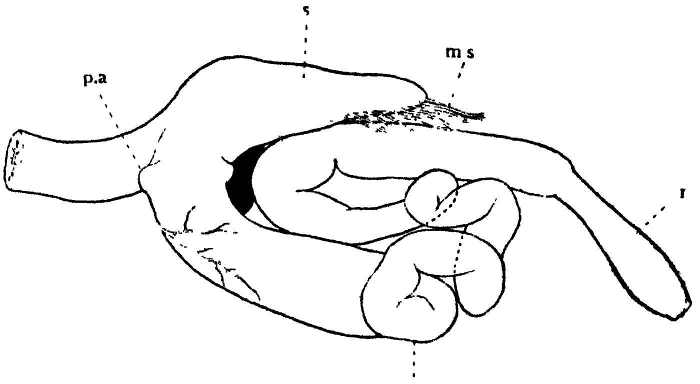


Fig. 104. *Branchiostegus japonicus.*

Liver thick, 2 lobes, right lobe larger than the left, lifting the stomach from below; gall-bladder long ellipsoid. Mesentery well developed. Spleen small situated at the right below of stomach. Air-bladder large and wide.
B. Feeding Habits.

One of the 2 samples (30.1 and 31.4 cm in body length) which I had obtained from the Tokyo Fish Market on October 12, 1935 had eaten quite a lot of shrimps belonging to the family Penaedae but the other had an empty stomach. The stomachs of the 5 samples (ave. 24 cm) caught by Mr. S. Miyauti, with a net, off the coast of Aziro, Izu Peninsula, on May 8, 1937 contained horse-mackerels, gobies, cuttle-fishes, shrimps, clam-worms, and fragments of shell-fishes, and the 7 samples (about 26 to 29 cm) which I collected off the coast Tateyama, Tiba Pref., on June 12 of the same year had eaten shell-fishes, shrimps and mud. Suzuki (1931) said that this fish had its habitat near muddy bottoms in rather deep waters, 50 to 60 meters in depth. For this reason, when the fish is brought to the surface, the air-bladder becomes enlarged owing to the decline in pressure. The air-bladder thus enlarged presses against the stomach which, in turn, is turned out into the mouth cavity, when consequently, the contents of the stomach are often thrown up.

Family APOGONIDAE

76. *Apogon lineatus* (Temminck et Schlegel) : Tenzikudai.

A. Digestive System.

Body oblong, compressed. Head large. Mouth large (m-c being ca. 2/5 of head length), directed obliquely upwards. Villiform teeth on jaws, vomer, and palatines; no canines Mouth cavity large, tongue rather large, trianguloid, flat, thick, teeth and melanin chromatophores both lacking on the surface (Pl. III, Fig. 3). Villiform teeth grow thickly on the upper and lower pharyngeal bones. Gill-rakers long and slender (the length being a little shorter than the corresponding gill-filaments), tips rather pointed, closely set, 19 in average number.

Peritoneal cavity rather large; no melanin chromatophores on the peritoneum. Stomach very large, Y-shape, consisting of small cardiac and pyloric parts and a very large blind sac; wall thick, folds of the mucous membrane longitudinal. Intestine rather short (the length being about 2.5 times d∼a), moderately wide, wall thin and black, winds twice as shown in the figure; mucous membrane consisting of short papillary processes. Pyloric appendages broad and long, 4 (rarely 5) in number, 2 of which are located on the left side of the stomach and the remainder on the right.

Liver incomplete 2 lobes, the left lobe being much larger than the right; gall-bladder small ellipsoidal. Air-bladder with thin wall.

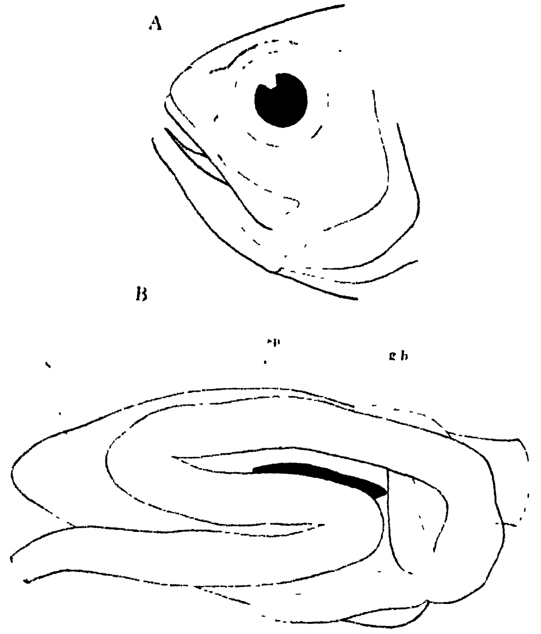


Fig. 105. *Apogon lineatus.* A. Head. B. Digestive tract.

Points that require special mention regarding the digestive system of this fish are that the stomach and intestine are greyish black, while the pyloric appendages are black. Cuvier and Valenciennes said in their book that *Apogon imberbis* has 4 pyloric appendages (note that it is the same number as the present species).

B. Feedihg Habits.

This fish lives in schools near the muddy bottom of shallow places in bay and feeds on small Crustacea which are found there and sometimes on very small larval fishes. This fish is known for sheltering its eggs in its mouth. Of the 24 that I examined, I came across 3 males that had swallowed the eggs which they were supposed to be sheltering. I also found that when the eggs matured and weighed 1/5 of the body weight, it ceased taking food.

Table 23

Stomach contents of *Apogon lineatus*

Species	Date	Locality	Number of fish	Body length (cm)	Stomach contents
Apogon lineatus	Mar. 18, 1936	Imabari, Ehime Pref.	58	4.1~5.1	Isopoda, etc.
	June 18, 1936	Ogôri, Yamaguti Pref.	161	4.5~6.6	Larval fishes (Gobiidae) Zoëa larvae, own eggs
	Oct. 9, 1938	Kasaoka, Okayama Pref.	30	5.4~6.9	Zoëa larvae, *Noctiluca*
A. semilineatus	Nov. 4, 1934	Enoura, Sizuoka Pref.	11	7.7~8.5	Small shrimps, own eggs

77. *Apogon semilineatus* (Temminck et Schlegel): Nenbutudai.

A. Digestive System.

This species is almost the same as the foregoing, except that some of them have 1 or 2 more gill-rakers and some that have a rather large right lobe of the liver. These may be given as the points of difference, but as I was able to examine only 11 of them, I am not in a position to give a definite statement.

B. Feeding Habits.

There are no material difference in comparison to the foregoing species.

Family SCOMBROPIDAE

78. *Scombrops boops* (Houttuyn): Mutu.

A. Digestive System.

Body rather elongate, dorsal and ventral contours evenly rounded. Head elongate, pointed. Mouth not large (m-c being ca. 2/5 of head length), pointed, not very oblique. Lower jaw slightly projecting; premaxillary not protractile. Lips thin. Upper jaw with 12 sets of teeth in a row and 3 sets of large teeth in another row inside; lower jaw with 16 sets in 1 row and another row of a set of small teeth outside. All teeth anchylosed, canine-like, very sharp, and curve slightly in. The size of teeth in both the upper and lower jaws about the same, but those in the middle of each row are larger than those in the front and back; the distance between each tooth is the same as the length of the tooth (Pl. I, Fig. 3); about 40 small teeth on the vomer; 20 to 30 teeth of approximately the same size on each side of the palatine in either 1 or 2 rows. Buccal cavity rather large; mucous membrane of oral cavity blackish blue. Plica palatinae not developed. Palate almost flat, having a few longitudinal folds. Tongue middle size, square, shovel-shaped, concave towards the tip, very thin, free, rather soft, the same colour as the mucous membrane of oral cavity. 1 set of narrow teeth band on the tongue which joins to 2 sets on the copulae making in all 3 sets of teeth bands. Closely set conical teeth on the upper and lower pharyngeal bones, viz. 3 sets, the front, middle, and back of pharyngeal teeth on the upper pharyngeal bone, and 1 set of narrow teeth band on the lower. Gill-rakers on the first arch number from 20 to 26 (the few at the front and back of which are rudimentary), long (a little longer than corresponding gill-filaments), rather flat, tips not pointed, vertical to the gill arch, coarse, 1 to 2 rows of 40 or 50 processes on each gill-raker. Pharynx large, having a rather deep groove.

Peritoneal cavity rather large, stretches just beyond the anus; melanin chromatophores absent in the peritoneum. Oesophagus short and broad, wall thick. Stomach moderately large, ┤-shape, blind sac about 3 times the length of the cardiac part; pyloric part about the length of the cardiac part; the thickness of these parts almost the same; wall of stomach thick, stand quite a bit of dilatation; cardiac part and blind sac about 10 wide longitudinal folds. Numerous veins cover the stomach. Intestine winds twice, forming the letter N, lower-right of the stomach; duodenum not so wide; middle intestine succeeding the duodenum and running towards the anus, makes a turn of 360° almost directly above the anus, assuming its course when it comes to the lower-right of the pyloric part, makes another turn of 360° and runs towards the anal fin and opens just in front of the anus, the length of which being ca. 4/5 times body length, ca. twice o~a and ca. 2.2 times d~a; narrow, wall thick; mucous membrane forming papillae on a zigzag foundation (Pl. IX, Fig. 7); there is a valve between the intestine and the rectum; mesentery poorly developed. Pyloric appendages large and long, 5 to 6 on the left side of the stomach and 7 to 8 on the right.

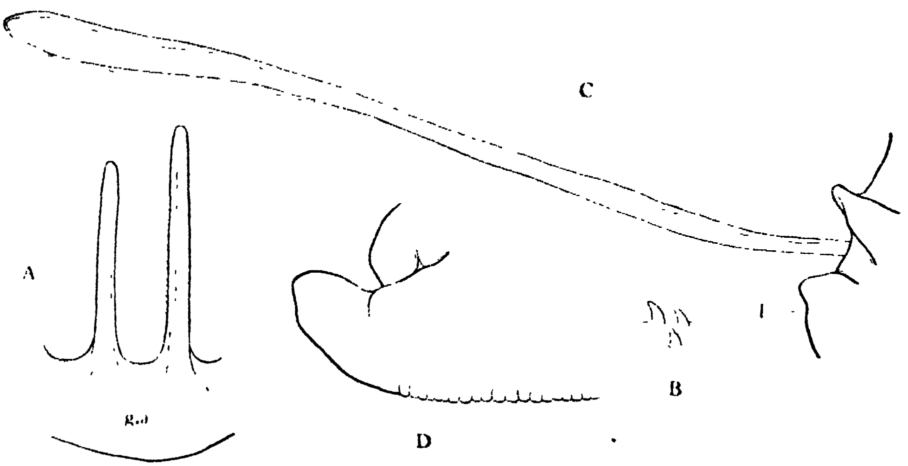


Fig. 106. *Scombrops boops*. A. Gill-rakers. B. Jaw-teeth. C. Gall-bladder. D. Margin of liver.

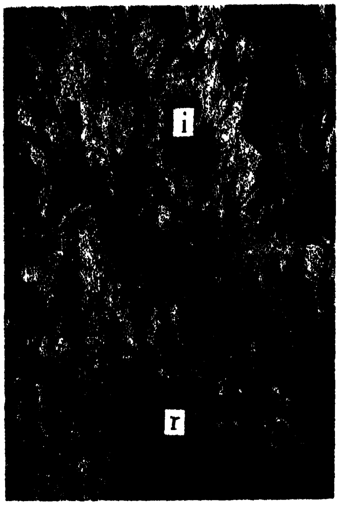


Fig. 107. *Scombrops boops.* Folds of mucous membranes of intestine and rectum.

Liver embraces from below the front half of stomach and a part of the pyloric appendages, small, contrary to the left lobe being long, the right is not well developed. Gall-bladder a long tube; Ductus choledocus also long; end of the gall-bladder extending to the first turning of the middle intestine above the anus. Pancreas distributed among the clusters of pyloric appendages and along intestine. Islets of Langerhans small, located at the beginning of Ductus choledochus, 3 to 6 in number. Spleen situated near the duodenum, moderately large. Air-bladder moderately large, wall thick. Genital organ growing big, often presses the intestine down.

B. Feeding Habits.

This fish belongs to the deep-sea fishes and in summer lives at a depth of over 400 fathoms, but in spring migrates to shallow waters less than 200 fathoms for spawning. The materials which I had handled were collected in spring and showed the following stomach contents, as shown in Table 24.

Table 24

Stomach contents of *Scombrops boops*

Date	Locality	Body length (cm)	Body weight (g)	Stomach contents
Apr. 8, 1936	Ôsaka Fish Market	59.9	—	Large number of lantern-fishes
	,,	60.2	—	,,
Mar. 24, 1937	Tokyô Fish Market	53.0	—	Deep-sea shrimps
,,	,,	51.5	- -	None
Mar. 17, 1939	,,	42.5	1640	Gonostomidae
,,	,,	42.5	1880	Indistinct
,,	,,	44.0	1940	Bones of fishes etc.

The results of this examination showed that they consisted chiefly of deep-sea fishes, such as the lantern fish, or those which belong to Gonostomidae, and shrimps which evidently have their habitat near rocks, from which it may be seen that this fish takes these species for its staple food. It is worthy of note that it also takes its food during the spawning season.

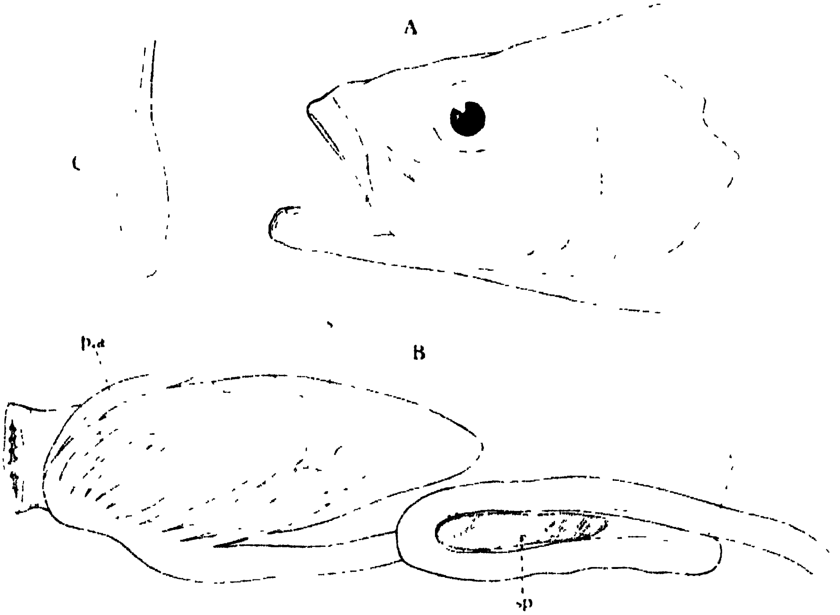
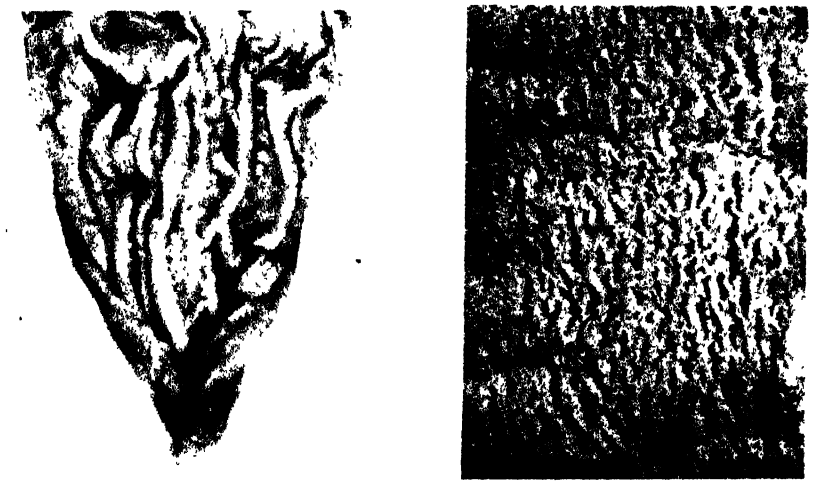


Fig. 108. *Lateolabrax japonicus*. A. Head. B. Digestive tract. C. Gall-bladder.



A B

Fig. 109, *Lateolabrax japonicus*. A. Folds of mucous membrane of stomach. B. The same of intestine.

Family SERRANIDAE

79. *Lateolabrax japonicus* (Cuvier): Susuki.

A. Digestive system.

Body elongate, compressed. Mouth moderately large (m-c being ca. 5/19 and m-b 1/4 of head length); lower jaw slightly longer than the upper. Bands of villiform teeth on the jaws, vomer and palatines. Mouth cavity large; tongue rather large, long, triangular, free, no teeth but quite a lot of melanin chromatophores on the surface, especially along the edge. Pharyngeal teeth villiform, closely arranged on the 3 sets of the upper pharyngeal bones. Gill-rakers rounded and long (the length being trifly shorter than corresponding gill-filaments), tips blunt, grow apart, 20 to 24 in number, process on each gill-raker numerous.

Peritoneal cavity moderately large, some melanin chromatophores on the peritoneum. Oesophagus short, wall rather thick. Stomach rather large, ⊣-shape; cardiac part broad; blind sac large; pyloric part short and small; wall of stomach thick; mucous membrane of the blind sac being particularly distinct and consisting of 7 to 8 wavy longitudinal folds. Folds of the blind sac connect with those of the pyloric part. Intestine rather short (the length being about twice d∼a), curves twice (in N-form type of winding), wall rather thick, mucous membrane net-work (Pl. XI, Fig. 19), it being divided into the middle intestine and the rectum by a valve. Anus opens just in front of the anal fin. Pyloric appendages rather short and slender, almost of the same length, located on the left side of the stomach, 15 in number.

Liver 2 lobes, the left being much larger than the right, lifting the stomach from below. Gall-bladder ellipsoidal; cystic duct fairly long. Spleen small, located near the second turning of intestine. Air-bladder long and rather large, wall thick.

B. Feeding Habits.

I could not obtain enough material to ascertain the feeding habits of this fish, but on examination of the stomach contents of 12 fishes (24.3 to 25.4 cm in body length) collected from the adjacent waters of Ogôri, Yamaguti Prefecture, in July 1936 and 7 fishes (30.1 to 32.8 cm in body length) collected around Kurihama, Kanagawa Prefecture, in August 1938, I found small fishes, crabs, clam-worms and sea-weeds, principally *Zostera*, from the first lot and *Euphausia*, small-fishes and fish eggs from the latter. It would therefore seem that the adults of this species are found in the middle stratum of the sea where there are sea-weeds and feed on the many small animals thereabouts. According to anglers, this fish eats principally at night. The young enters the river in summer and goes in energetic pursuit of food.

80. *Bryttosus kawamebari* (Temminck et Schlegel): Oyanirami.

A. Digestive System.

Body oblong, moderately compressed. Mouth large (m-c being ca. 1/3, m-b ca. 2/7 of head length), directed obliquely upwards; jaws almost equal.

Villiform teeth in bands in jaws and on vomer and palatines, some of the anterior teeth in both jaws slightly enlarged. Tongue medium in size, elliptic, free, no teeth, with a few melanin chromatophores. Pharyngeal teeth villiform, grow densely on 3 sets of the upper pharyngeal bones. Gill-rakers broad and short (about half the length of corresponding gill-filaments), 7 in number, flat, coarsely grown.

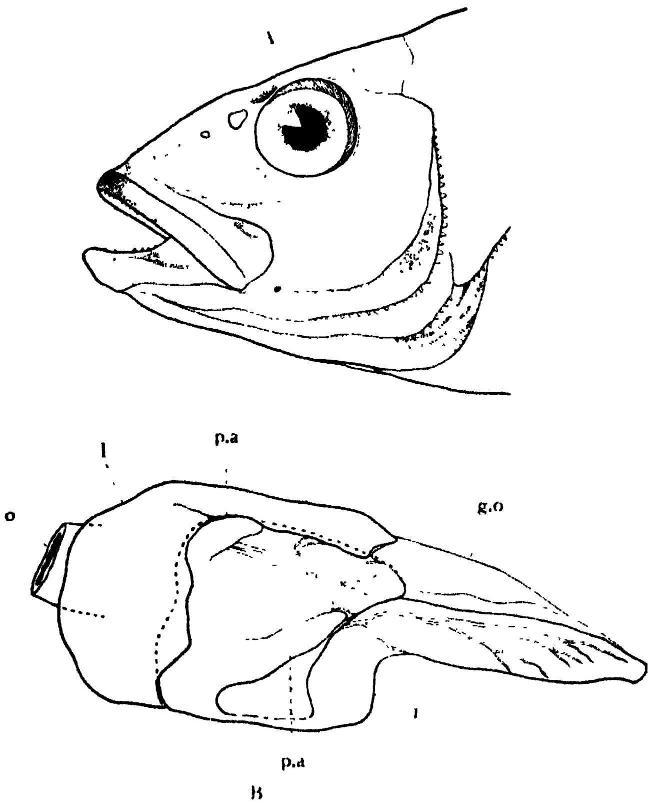


Fig. 110. *Bryttosus kawamebari*. A. Head. B. Digestive tract.

Peritoneal cavity moderately large; blood vessels densely distributed on peritoneum (no melanin chromatophores). Oesophagus rather long and broad. Stomach medium in size, Y-shape, wall thick, mucous membrane consists of longitudinal folds and transversal folds between them. Intestine short (the length being ca. 1.4 times d~a), winds U-form, wide, mucous membrane consists of net-work folds. Pyloric appendages rather short, 2 in number.

Liver large, 2 lobes, left lobe larger than the right; gall-bladder small and ellipsoidal. Air-bladder elongated.

B. Feeding Habits.

This is a fresh-water fish found in various rivers in southern Japan. In the August 18th, 1935 issue of the Tokyo Nitiniti Sinbun, there was an interesting article on the feeding habits of this fish by Mr. Takizawa.

According to his observation of those he cultures in an aquarium, he has to keep a very close eye on the females as they devour the young. The interesting part of it is that the males watch over the young and when the females approach to eat them, they make a furious attack in an attempt to protect them.

81. *Stereolepsis ischinagi* (Hilgendorf) : Isinagi.

A. Digestive System.

Body robust, moderately compressed. Mouth moderately large (m-c being ca. 1/3 of head length); upper jaw slightly longer than the lower. Teeth in broad villiform bands on jaws, vomer and palatines. Mouth cavity rather large; tongue medium in size, long rectangular, thin, free anteriorly, smooth, a few melanin chromatophores on the surface. Pharyngeal teeth densely grown, slightly longer than those of jaws. Gill-rakers short (shorter than corresponding gill-filaments), stout, flat, coarsely grown, 11 to 12 in number.

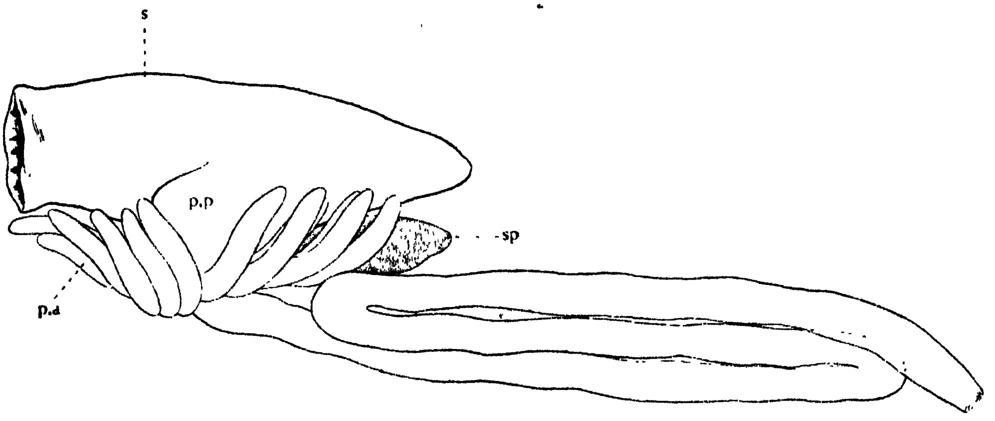


Fig. 111. *Stereolepsis ischinagi.*

Stomach large, ┤-shape, wall thick, the folds of mucous membrane longitudinal. Intestine moderately long (the length being ca. 2.8 times d∼a), winds twice, wall rather thick, mucous membrane consists of net-work folds (Pl. X, Fig. 15). Intestine divided by a valve into the middle intestine and the rectum. Pyloric appendages moderately long and broad, tips blunt, 12 in number.

Liver rather small, 2 lobes, thick, left lobe larger than the right; gall-bladder long ellipsoid. Spleen rather large, located near the blind sac of stomach. Air-bladder elongate.

B. Feeding Habits.

This fish is found in almost all parts of Japanese waters but northern Japan has the largest production. Generally, it is found among the rocks in a depth of 400 to 500 meters, but from May to June, at the spawning season, it migrates to rocks in shallow waters. Fishermen use rods or long-line to fish them at this time, using cuttle-fish, mackerel, flat-fish and sardine for baits.

When I examined the stomach contents of those (2 of them — 43 kg, 108 cm, ♂; 22.4 kg, 81 cm, ♂) caught on May 19th, 1936 off the coast of Tyôsi, Tiba Pref., the bigger one had eaten 5 cuttle-fishes, about a foot long. The stomachs of the samples examined by Mr. H. Matida of the Hiyama Branch of the Government of Hokkaidô caught on July 8th, 1939 around Esasi, Hokkaidô, contained mostly bottom fishes. This information was contained in a letter from Mr. Matida who made this examination specially for me.

82. *Epinephelus septemfasciatus* (Thunberg): Mahata.

A. Digestive System.

Body elongate, compressed. Mouth large (m-c being ca. 1/3, m-b ca. 1/2 of head length), slightly oblique upwards; lower jaw a little longer than the upper. Teeth small and canine in 2 or 3 rows on each side; there are hinged teeth too, those on vomer and palatines villiform. Tongue, contrary to the size of the mouth cavity, is extremely small, semi-elliptic, free, moderately thick, melanin chromatophores on the anterior part, and no teeth on the surface. Mm. hypobranchiales extra well-developed. Somewhat large pharyngeal teeth grow close together on 3 sets of the upper and 1 set of the lower pharyngeal bones. Gill-rakers short (the length being approximately the same as corresponding gill-filaments), flat, tips pointed, grow apart, 31 in number of average, process on each gill-raker being numerous (Pl. IV, Fig. 7).

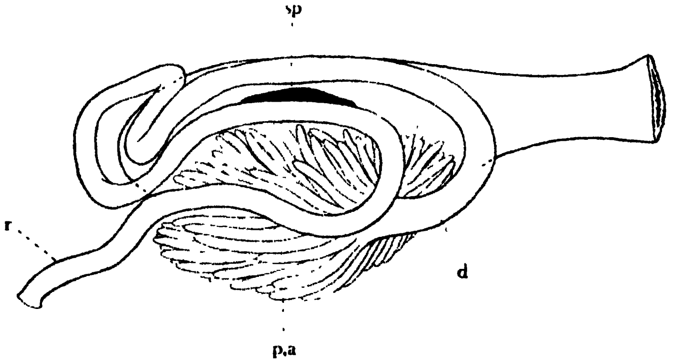


Fig. 112. *Epinephelus septemfaciatus.*

Peritoneal cavity rather large; no melanin chromatophores on the peritoneum. Stomach large, ┤-shape, wall thick, mucous membrane longitudinal serpentine folds; pyloric part small. Intestine longer than any of the species mentioned above, belonging to Serranidae (the length being ca. 3.5 times d~a) and winds as illustrated (may be considered a transformation of the N-form type of winding), wall rather thick, mucous membrane irregular and distorted folds which appear to form a kind of net-work. End of the intestine is the rectum divided by a valve. Pyloric appendages in a oblong bunch, 150 to 160 in number.

Liver large, thick, 2-lobed, the left being the larger lobe, lifting the stomach from below; gall-bladder small, a rather long ellipsoid. Air-bladder large, located at the upper back part of the peritoneal cavity.

B. Feeding Habits.

When I examined the stomach contents of 5 samples (21.6 cm in body length and 405 g in body weight in average) caught at Mito, Sizuoka Pref. in November 1934, they consisted of fish bones, worms and sea-weeds. As my investigation is based upon so little material, I am unable to say anything definite about its feeding habits, but I am inclined to think that they differ quite materially to those of *Lateolabrax japonicus.*

In connection with the digestive organs of serranoid fishes, Jacobshagen (1919) examined those of *Serranus cabrilla* and found that it had a wide stomach with a thick wall, an intestine with also a rather thick wall, and a valve which divided the middle intestine and the rectum, and 6 pyloric appendages. Eggeling (1908) said that *S. cabrilla* had a long intestine with a thick wall, and that the pyloric appendages numbered 9. In Vol. II of Cuvier and Valencienne's book, the stomach wall of *Epinephelus gigas* is described as being thick and the pyloric appendages as numbering 19 to 20. It is interesting to note that while there is very little difference in the description given by those mentioned above and mine, only the number of the pyloric appendages seems to differ according to their species, even though they come from the same family.

Family SCIAENIDAE

83. *Nibea mitsukurii* (Jordan et Snyder): Nibe.

A. Digestive System.

Body oblong-elongate, rather compressed. Mouth medium in size (m-c being ca. 2/7, m-b ca. 1/4 of head length), protrusile; upper jaw a little longer than the lower; lips rather wide but thin; teeth in each jaw in a narrow band, outer series of upper jaw teeth and inner series of the lower large. Mouth cavity moderately large; no teeth on vomer and palatines. Tongue large, rectangular, thin, free, orange in colour (Pl. III, Fig. 7). Pharyngeal teeth robust, tips blunt, coarsely grown. Gill-rakers rather long (the length being ca. 2/3 of corresponding gill-filaments), flat, tips pointed, 22 to 27, process on each gill-raker numerous.

Peritoneal cavity moderately large. Oesophagus short but wide, wall thick. Stomach rather small, ˥-shape; blind sac long; mucous membrane of blind sac consists of about 10 longitudinal serpentine folds, while those of cardiac part and pyloric part net-work. Intestine broad, short (the length being ca. 1.2 times d～a), wall thin, making 2 short windings, folds of the mucous membrane longitudinal (Pl. IX, Fig. 2), but the surface almost flat. Pyloric appendages broad and short, tips blunt, 5 in number. Accord-

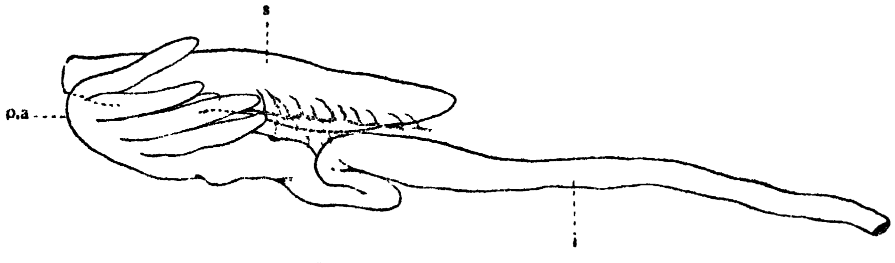


Fig. 113. *Nibea mitsukurii.*

ing to Cuvier and Valenciennes, *Sciaena aquila* has 10 pyloric appendages.

Liver small, 2 lobes; gall-bladder very long, stretching along the intestine. Pancreas diffused between the stomach and the intestine. Air-bladder large, wall very thick.

B. Feeding Habits,

I examined the stomach contents of 16 fishes (28–42 cm) which were collected from the Tokyo Fish Market, on May 19, 1936. 3 of which had taken the Japanese tongue soles, viz. *Rhinoplagusia japonica*, and 2 of which certain larval fishes in their stomachs.

84. *Nibea argentata* (Houttyn): Isimoti.

A. Digestive System.

Mouth rather large (m-c being ca. 3/7 of head length), protrusile; lower jaw slightly included when the mouth is closed. Teeth in jaws small, in bands; no teeth on vomer and palatines. Tongue large, triangular, free anteriorly, rudimentary teeth on the surface, no melanin chromatophore. Pharyngeal teeth almost the same as the foregoing. Gill-rakers short (the length being ca. 1/4 of corresponding gill-filaments), flat, tips rather pointed, coarse, 13 to 18 in number.

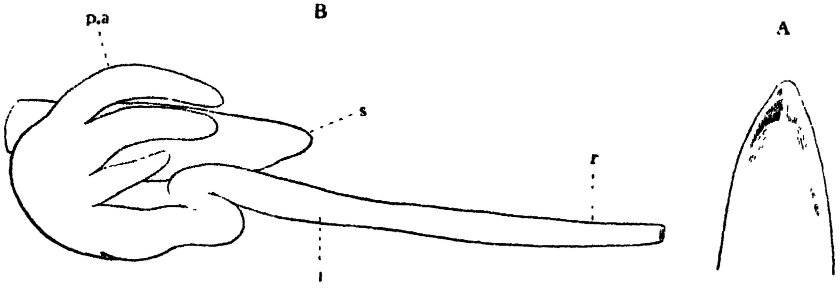


Fig. 114. *Nibea argentata.* A. Tongue. B. Digestive tract.

Peritoneal cavity moderately large; melanin chromatophores scattered on peritoneum. Stomach ┤-shape, rather small, wall rather thick, mucous membrane consists of longitudinal serpentine folds. Intestine short, having the characteristic winding, as in the case of the above-mentioned species, wall moderately thick, mucous membrane has few folds. Pyloric appendages large, 3 in number, 2 of which longer than the rest.

Liver rather long but thin, 2 lobes; gall-bladder long and slender. Air-bladder large, wall thick.

B. Feeding Habits.

This fish is a bottom feeder. It feeds usually on the shrimps and the clam-worms.

Family SILLAGINIDAE

85. *Sillago sihama* (Forskål): Kisu.

A. Digestive System.

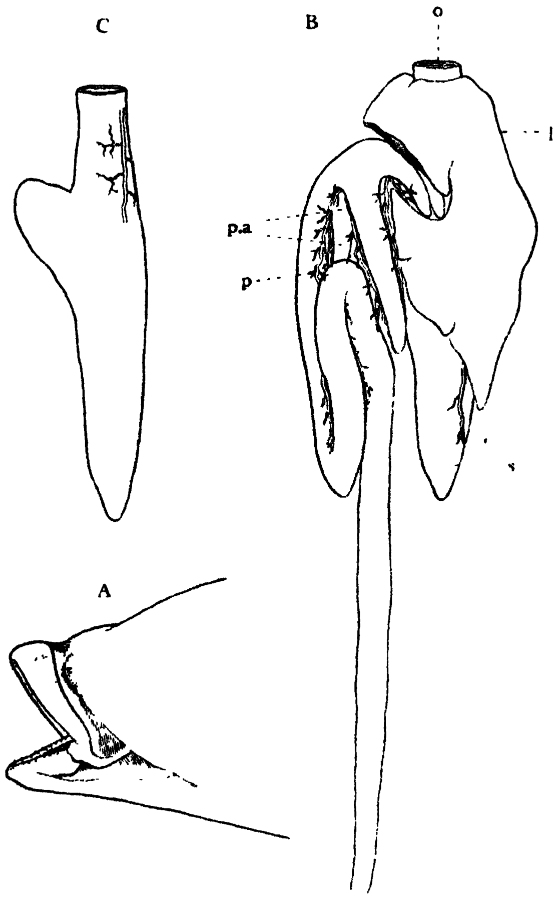


Fig. 115. *Sillago sihama*. A. Mouth. B. Digestive tract. Ventral side. C. Stomach.

Body elongate, slightly compressed. Mouth small (m-c being ca. 2/13, m-c 3/13 of head length); premaxillary more or less protrusile; upper jaw a little longer than the lower. Teeth in jaws minute, in narrow bands. Mouth cavity rather small, minute teeth on vomer but none on palatines. Tongue medium in size, triangular, thick, free anteriorly, small papillary processes on the surface, no melanin chromatophore (Pl. III, Fig. 1), Mm. hypobranchiales well-developed. Minute conical teeth on each of 3 sets of upper pharyngeal bones, and small ones in 3 rows on 1 set of lower pharyngeal bone. Gill-rakers short (the length being ca. 2/7 of corresponding gill-filaments), slender, tip pointed, 13–14 in number, process on each gill-raker few (Pl. IV, Fig. 6).

Peritoneal cavity rather small; peritoneum silvery and rich in melanin chromatophores. Oesophagus short with thick wall, mucous membrane consists of 10 longitudinal folds. Stomach small, ┤-shape, consists of rather long cardiac part, long blind sac and short pyloric part, wall rather thick, mucous membrane consists of about 10 longitudinal serpentine folds (Pl. VI, Fig. 7). Intestine short (the length being ca. 14 times d~a), narrow, winds twice, wall rather thin, the folds of mucous membrane net-work. Pyloric appendagas 4, and 1 of which longer than the rest.

Liver rather large, 2 lobes, located on the left ventral of stomach. Pancrese well-developed, locating between the pyloric appendages and the turning part of intestine. Air-bladder large, wall thick.

B. Feeding Habits.

Judging from the analysis of the stomach contents, it would seem that this fish is bottom feeder.

Table 25

Stomach contents of *Sillago sihama*

Date	Locality	Number of fish	Av. body length (cm)	Stomach contents
Aug. 3, 1928	Misaki, Kanagawa Pref.	10	—	*Nereis* sp., young squill, certain Isopoda, etc.
Sept. 15, 1931	Bay of Tokyo	20	16.4	*Eupagurus* sp., *Thelepus* sp. (Polychaeta), *Nereis* sp., sand particles

86. *Sillago japonica* (Temminck et Schlegel): Awogisu.

A. Digestive System.

There is not such a great deal of difference in the digestive system of this fish and the above mentioned species, but I shall describe the differences as they are: tongue trianguloid; Mm. hypobranchiales more developing; gill-rakers a little shorter (the length being ca. 1/4 of corresponding gill-filaments), 8–11 in number; liver of the above mentioned species consists of large left lobe and small right one, while that of the present species consists of small left one and large right one. Form of stomach, length and winding type of intestine, folds of the mucous membranes of these 2 parts, number of pyloric appendages are similar to those of above mentioned species.

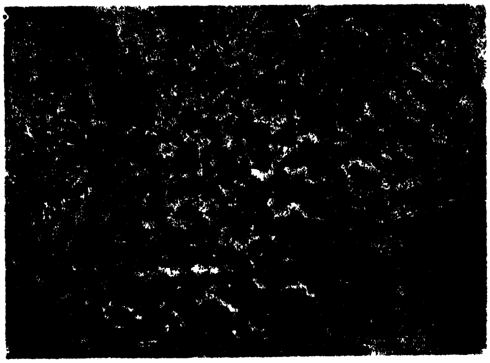


Fig. 116. *Sillago japonica*. Folds of intestinal mucous membrane.

B. Feeding Habits.

By the courtesy of Mr. S. Miyauti, I was able to obtain 5 fishes (16.2–17.8 cm in body length) from the neighboring waters of Hunabasi, Tiba Pref. on May 22, 1937. I found the bottom living creatures such as Isopoda, Paguridae, Nereidae, shell-fishes and sand particles in their stomachs.

Family GIRELLIDAE

87. *Girella punctata* (Gray): Mezina.

A. Digestive System.

Body oblong-ovate, compressed. Mouth rather small (m-c being ca. 1/5 of head length), directed obliquely upwards; jaws equal; a series of tricuspid teeth in both jaws backed by a band of much smaller teeth. Mouth cavity rather large; no teeth on vomer and palatines; tongue large, trapezoidal, not free, smooth, soft, no melanin chromatophore. Gill-rakers long (the length being a little shorter than corresponding gill-filaments), tips blunt, soft, flat, 28 in number average of, numerous soft processes on each gill-raker. Pharyngeal teeth long and slender, closely set.

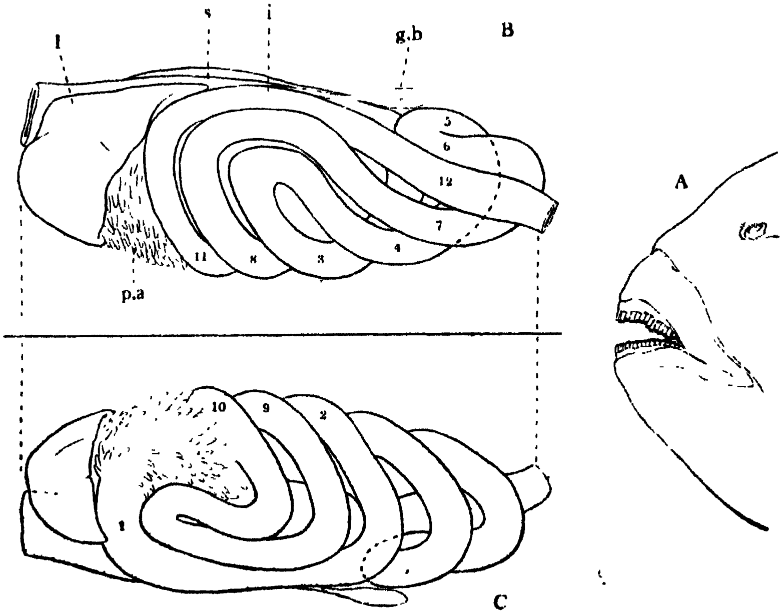


Fig. 117. *Girella punctata.* A. Head. B., C. Digestive tract.

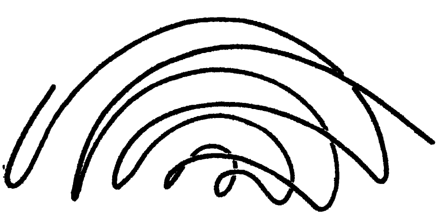


Fig. 118. *Girella punctata.* Diagram showing the winding type of intestine.

Peritoneal cavity large; peritoneum thin and black. Stomack ┐-shape, medium in size, wall rather thin, mucous membrane with longitudinal serpentine folds. Intestine long, winds several times, as shown in the figure; wall thin; mucous membrane consists of very long papillary processes (Pl. XII, Fig. 29). Pyloric appendages short and small, tips pointed, about 150 in number.

Liver 2 lobes, medium in size, lifting the cardiac part of the stomach from left to right; gall-bladder slender; cystic duct long. Air-bladder large, wall thick, stretches right above the digestive organs.

B. Feeding Habits.

It is customary for this fish to have its digestive tract always filled with food. My observation was based upon the material as shown in the table, according to which I may say that although it is a herbivorous fish, it does not specialize in herbs so much as *Siganus fuscescens*, and it may be safer to classify it with the omnivorous.

Table 26

Stomach contents of *Girella punctata*

Date	Locality	Number of fish	Av. body length (cm)	Stomach contents
Aug. 13, 1936	Tokyo Fish Market	3	30.3	Phaeophyceae, *Gammarus* sp.
Aug. 11, 1937	Misaki, Kanagawa Pref.	1	29.0	*Nereis Agassizi*, *Sargassum bacciferum*
Sept. 4, 1937	”	12	28.7	Certain Polychaeta, *Sargassum enerve*, *Ceramium tenerrimum*
Oct. 19, 1938	Tokyo Fish Market	5	31.2	Certain Polychaeta, Phaeophyceae

Family SPARIDAE

88. *Pagrosomus major* (Temminck et Schlegel): Madai.

A. Digestive System.

Body elongate, rather deep, compressed. Head large; snout rather long and pointed. Mouth rather small (m-c being ca. 5/19 and m-b ca. 5/13 of head length), almost horizontal; the upper jaw being slightly longer than the lower; lips thin. Upper jaw has 2 series of teeth, that is, they consist of the inside and outside series; the outside series in 3 rows are large (the outside row consisting of 2 large canine teeth, the middle row of small canine and 7 molar teeth, and the inside row of molars); and the inside series are all granular teeth. Teeth in lower jaw are similarly arranged as those of the upper. Mouth cavity rather small; palatal mucous membrane consisting of 50 to 60 longitudinal folds; no teeth on vomer and palatines. Tongue moderately large and thick, triangular, free anteriorly, no teeth and melanin chromatophores on it. 3 sets of conical teeth, with brown tips, on the upper pharyngeal bone and 1 set on the lower (Pl. II, Fig. 2). Gill-rakers short (the length being ca. 1/3 of corresponding gill-filaments), flat, tips pointed, coarse, 14 to 16 in number.

Peritoneal cavity rather large; peritoneum silvery. Oesophagus wide but short, wall thick. Stomach rather small, V-shape or rather Y-shape, wall thick, blind sac short, mucous membrane with 10 wide longitudinal folds, between which are fine longitudinal folds (there being some transversal folds too) (Pl. VII, Fig. 14); wall of the pyloric part not especially thick. Intestine moderately long (the length being ca. 3.2 times d~a); duodenum broad, winds 4 times, wall thin; mucous membrane furnished with papillary processes like petals, as illustrated, a kind of net-work; intestine divided into the middle intestine and the rectum by a valve. Pyloric appendages broad and very short. 4 in number, located at the lower left of the cardiac part.

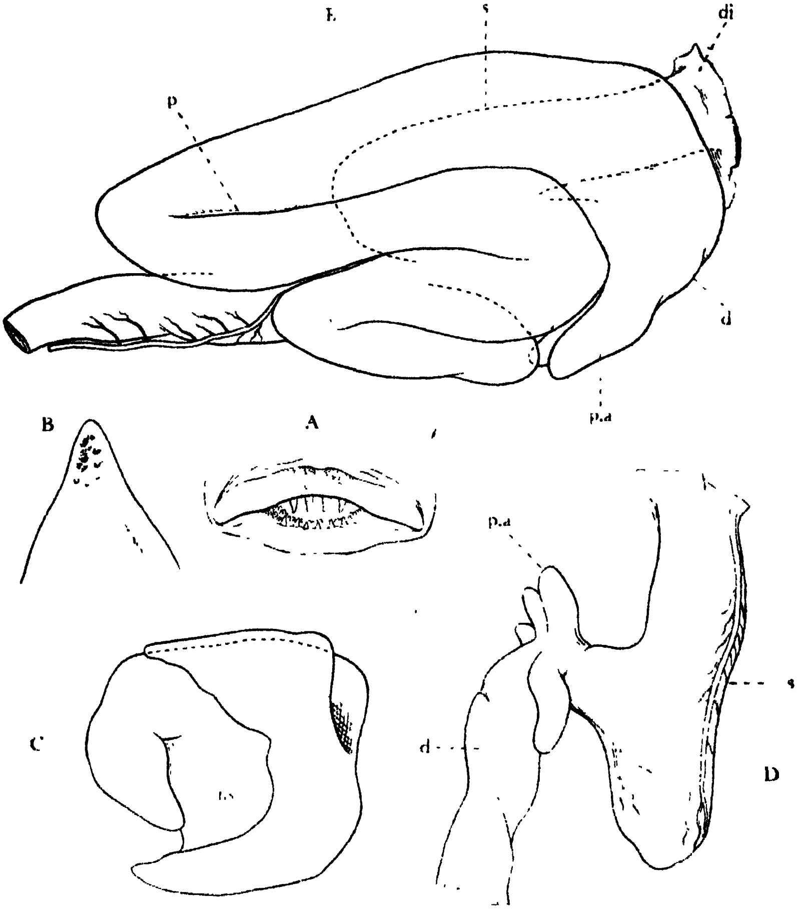


Fig. 119. *Pagrosomus major*. A. Frontal view of mouth. B. Tongue. C. Liver. D. Stomach. E. Digestive tract.

Liver medium in size, 2 lobes, embraces the anterior part of the stomach from below; gall-bladder a long sac. Air-bladder large, fusiform, stretching over the most upper part of the peritoneal cavity.

Kishinouye (1902) gave a rather detailed description the teeth of this fish, but Tanaka (1915, p. 316–317) gives a still detailed description. Kawamura (1914) reported on the digestive organs, and Okamoto (1918) described the stomach. Cuvier (1810) described the stomach of ***Pagrus spinifer*** as being big, but Okamoto says that he was misled by inspecting a stomach with a large quantity of contents.

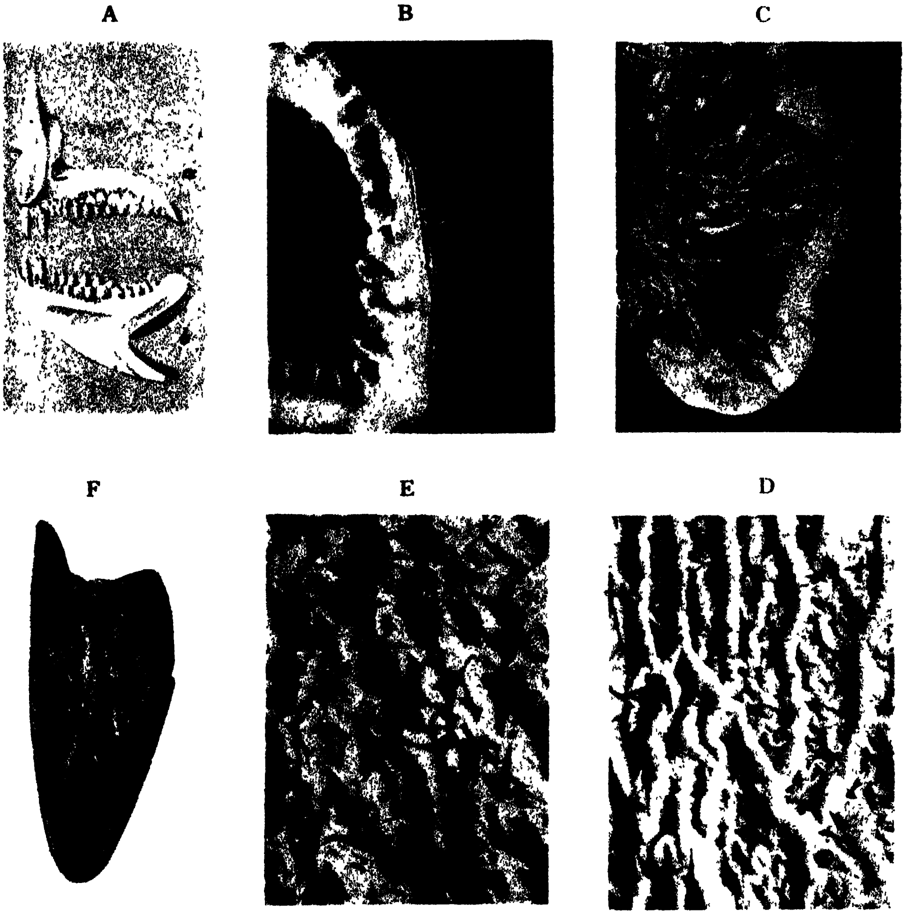


Fig. 120. *Pagrosomus major*. A. Jaw-teeth (After Kishinouye). B. Gill-raker. C. Mesentery. D. Folds of mucous membrane of intestine. E. The same of pyloric appendage. F. Cross section of liver.

B. Feeding Habits.

As regards the feeding habits of this fish, according to Kishinouye (1902), it feeds on Mollusca, such as shell-fish and cuttle-fish; on Crustacea, such as shrimps, crabs and squills; and on fishes such as sardines, horse-mackerels, and on the whole on bottom creatures such as sea-urchins and starfishss; according to Konno (1916), chiefly on Crustacea and Mollusca, sardines coming next; and Kaziyama (1937) expressed the opinion that as the young of this fish lives among sea-weeds, it feeds on any small creatures which it can get hold of nearby, and that as it grow up, it departs from the region of sea-weeds and favors shrimps.

Through the courtesies of Messrs. S. Fuzimori, S. Miyauti and K. Tanaka, I was able to collect a fair amount of adults and youngs of this species from various localities, and found, upon examination, that the adults particularly went in for bottom food and had a definite preference for shrimps. The results are shown in Table 27.

Table 27

Stomach contents of *Pagrosomus major*

Date	〃	〃	〃	〃	〃	〃	June ~ Sept. 1935	June 11, 1937	May 8, 1937	Jan. 27, 1939
Locality	Tomo, Hirosima Pref.	Takamatu, Kagawa Pref.	Komiya, Hyôgo Pref.	Miyazaki, Wakayama Pref.	Saizyô, Ehime Pref.	Ôyô, Hirosima Pref.	Nakanoseki, Yamaguti Pref.	Tokyo Fish Market	Aziro, Sizuoka Pref.	Ôhata, Yamaguti Pref.
Number of fish	10	11	5	2	8	20	3	20	17	2
Body length (cm) / Stomach contents	4.8—11.8	7.0—8.4	8.1—12.0	9.3, 10.7	5.0—8.3	5.3—10.7	6.3—9.2	ca. 25.0	10~15	ca. 30.0
Certain larval fishes								2	4	
Ikanago (*Ammodytes personatus*)								5	1	
Katakutiiwasi (*Engraulis japonicus*)			1							
Kurakakegisu (*Neopercis sexfasciata*)	1									
Certain crabs		1							1	
Megalopa larvae of crabs	4							1		
Yamatoebaria (*Ebalia japonica*)										
Certain shrimps		2	1		1	3		1	2	
Akaebi (*Penaeopsis akayebi*)	1	2								
Saruebi (*Trachypenaeus curvirostris*)						1				
Sergestes sp.						1				
Squills					2					
Euphausia				1						
Copepoda			1		2		2			
Balanus								2		
Cuttle-fishes									2	
Octopus-appendage									1	
Certain shell-fishes								3	3	
Certain clam-worms		1						1		
Isome (*Lumriconereis heteropoda*)								2		
Certain jelly fishes	1									
Igisu (*Ceramium rubrum*)						1				
Indistinct					1			1		
None	2	4	1	1	1	7	1	5	3	2

89. *Taius tumifrons* (Temminck et Schlegel) : Kidai.

A. Digestive System.

The digestive system of this fish is almost the same as the previous species. For instance, the stomach is V-shape; the winding and the length of the intestine is practically the same. In most cases, if it is of a different species, the number of pyloric appendages usually differs, but in this case, it is the same, 4. Only the jaw teeth are different: the present species is entirely devoid of molar teeth, and if we leave out the row of granular teeth, there is only 1 row.

B. Feeding Habits.

According to Kishinouye (1902), the principal food of this fish is Crustacea, Mollusca, Echinodermata and fishes. As this fish has no molar teeth, it cannot take the hard food (such as shell-fish, *Balanus*, etc.) like the previous species.

90. *Sparus swinhonis* (Günther): Kurodai.

A. Digestive System.

Mouth rather small (m-c being ca. 2/7 of head length). On each side of the upper jaw are 5 rows of molar teeth and in the anterior part 6 incisor-like pointed teeth, behind which is a broad patch of small molars; on the sides of the lower jaw are 3 rows of molars which is different from the upper, the other points being the same. Mouth cavity medium in size; tongue a moderately large and perfect triangle, rather thick, free anteriorly, no melanin chromatophores (Pl. III, Fig. 12); pharyngeal teeth minute but sharp and numerous; gill-rakers short (the length being ca. 1/5 of corresponding gill-filaments), flat and wide, tips pointed, 10 to 12 in number.

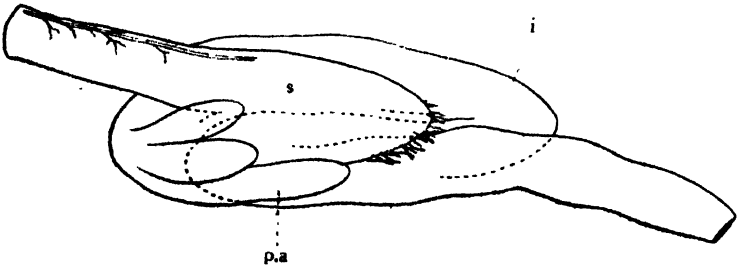


Fig. 121. *Sparus swinhonis.*

Peritoneal cavity rather large. Stomach V-shape, mucous membrane longitudinal folds with little warts between the folds. Intestine practically the same as the above-mentioned species (for instance, its duodenum wide; a valve divides it into the middle intestine and the rectum, etc.), the difference being that it makes 2 windings and the papillary processes of the mucous membrane are short. Pyloric appendages 4.

Liver consists of a big left lobe and a small right lobe; gall-bladder passing the left side of the stomach is a long sac and stretches to the side of the intestine.

B. Feeding Habits.

In August 1929, I obtained 12 of this fish (approximately 20 cm in body length) from Kotubo, Kanagawa Prefecture, and 10 (about 9.6 to 15.7 cm) from the adjacent waters of Mukô Island, Yamaguti Prefecture, in July 1936, and found that the stomach contents of the former lot consisted of shell-fishes and star-fishes, while the stomachs of the latter lot contained a large quantity of shrimps, squills, crabs, larvae of crabs, etc. The anglers say that although this fish is omnivorous and voracious in its feeding habits, it is very cautious about fishing hooks.

Family POMADASYIDAE

91. *Hapalogenys mucronatus* (Eydoux et Souleyet): Setodai.

A. Digestive System.

Body oblong, compressed. Mouth slightly oblique upwards, moderately large (m-c being ca. 1/3, m-b less than 1/3 of head length); lower jaw a little longer than the upper; premaxillary tolerably protractile; lips thin; fleshy barbels about the lower jaw. Teeth in jaws conical, in narrow band, outer ones enlarged. No teeth on vomer and palatines. Tongue rather large, triangular, free, no teeth and melanin chromatophores on the surface. Upper pharyngeal teeth developed. Gill-rakers short (the length being ca. 1/3 of corresponding gill-filaments), tips rather blunt, coarsely grown, 15 to 19 in number, process on a gill-raker numerous.

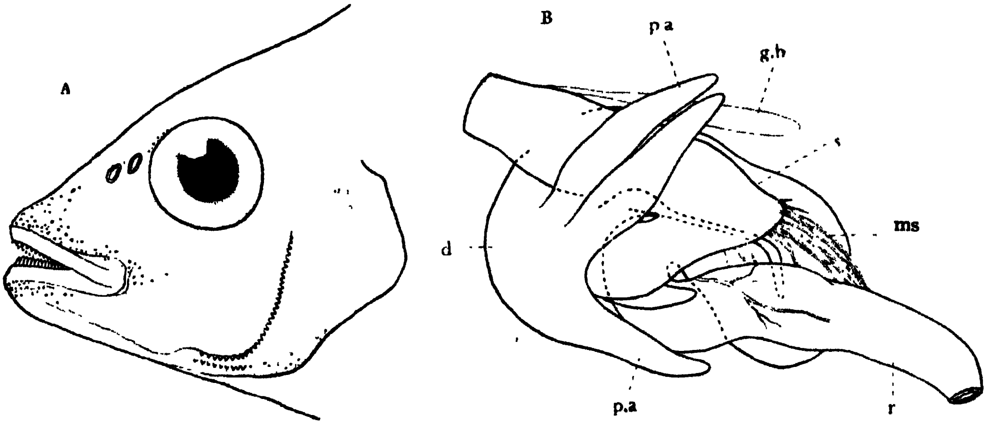


Fig. 122. *Hapalogenys mucronatus.* A. Head. B. Digestive tract.

Peritoneal cavity rather small and compressed; peritoneum black. Oesophagus short and wide, wall thick, mucous membrane consists of 14 to 15 longitudinal folds. Stomach moderately large, V-shape, wall thicker than that of oesophagus; cardiac part long, blind sac degenerated, pyloric part ovate and the wall very thick; mucous membrane of the stomach consists of longitudinal serpentine folds. Intestine short (the length being ca. 2.2 times d$\sim$a), wall moderately thick, winds twice, mucous membrane assumes about 25 longitudinal zigzag folds. Intestine divided into the middle intestine and the rectum by a valve. Pyloric appendages 4 in number, 2 of them are large and long.

Liver consists of incomplete 2 lobes (right lobe larger than the left), hanging over the anterior part of the digestive tract; gall-bladder long and slender, cystic duct longer than bile duct. Air-bladder large with thick wall.

B. Feeding Habits.

I examined the stomach contents of 5 fishes (4.2 to 7.0 cm) which were caught by a net on Mar. 26, 1936 from the adjacent waters of Mituhama, Ehime Prefecture. They had eaten the bottom living creatures, such as Paguridae, shrimps, shell-fishes, etc..

Family THERAPONIDAE

92. *Therapon oxyrhynchus* (Temminck et Schlegel): Simaisaki.

A. Digestive System.

Body oblong, rather compressed. Mouth moderate (m-c being ca. 1/3.3, m-b ca. 1/3.1 of head length), upper jaw longer than the lower. Teeth in jaws small, conical, set in many rows anteriorly in both jaws and posteriorly in the upper, while in 2 rows posteriorly in the lower; the teeth of outer rows slightly larger than the rest. Mouth cavity wide laterally; no teeth on vomer and palatines; tongue moderately large, thin, free, no teeth, few melanin chromatophores on the surface. Pharyngeal teeth small, conical. Gill-rakers short (the length being ca. 1/3 of corresponding gill-filaments), rather flat, base wide, coarsely grown, 23 to 24 in number, process on each gill-raker numerous.

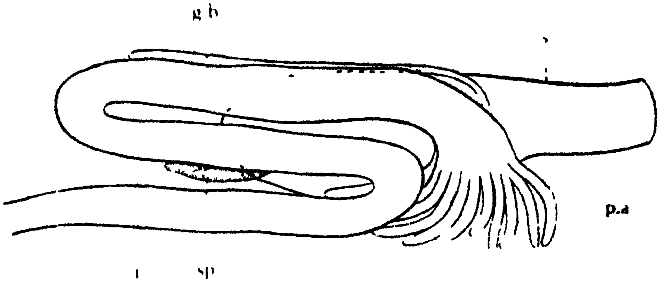


Fig. 123 *Therapon oxyrhynchus*

Peritoneal cavity moderately large; no melanin chromatophores on peritoneum. Oesophagus short and wide, wall thick, mucous membrane consists of 12 longitudinal folds and small papillae between them. Stomach V-shape, large, wall thick, mucous membrane consists of 5 to 6 longitudinal folds and many transversal folds between those folds; pyloric part short. Intestine rather short (the length being ca. thrice d~a), winds N-form, wall rather thick, mucous membrane with numerous small papillary processes. Pyloric appendage short, 12 in number.

Liver small, thin, 2 lobes, left lobe longer than the right; gall-bladder the long tube, cystic duct long. Spleen situates near the middle part of intestine, as shown in the figure. Air-bladder large, dumbbell-like, wall thick.

Cuvier and Valenciennes (1828–1849) describe in their book "Histoire naturelle des poissons" (Vol. 3) on the digestive tracts of *Therapon servus*, *T. cinereus*, *T. transversus* and *T. obscurus*. According to their descriptions, their pyloric appendages are unequal in number.

B. Feeding Habits.

According to my humble experience, it would seem that this fish lives on animals at or near the muddy bottoms where sea-weeds grow.

Family APLODACTYLIDAE

93. *Goniistius zonatus* (Cuvier et Valenciennes): Takanohadai.

I have already made a detailed report on the digestive system and feeding habits of this species.

A. Digestive System.

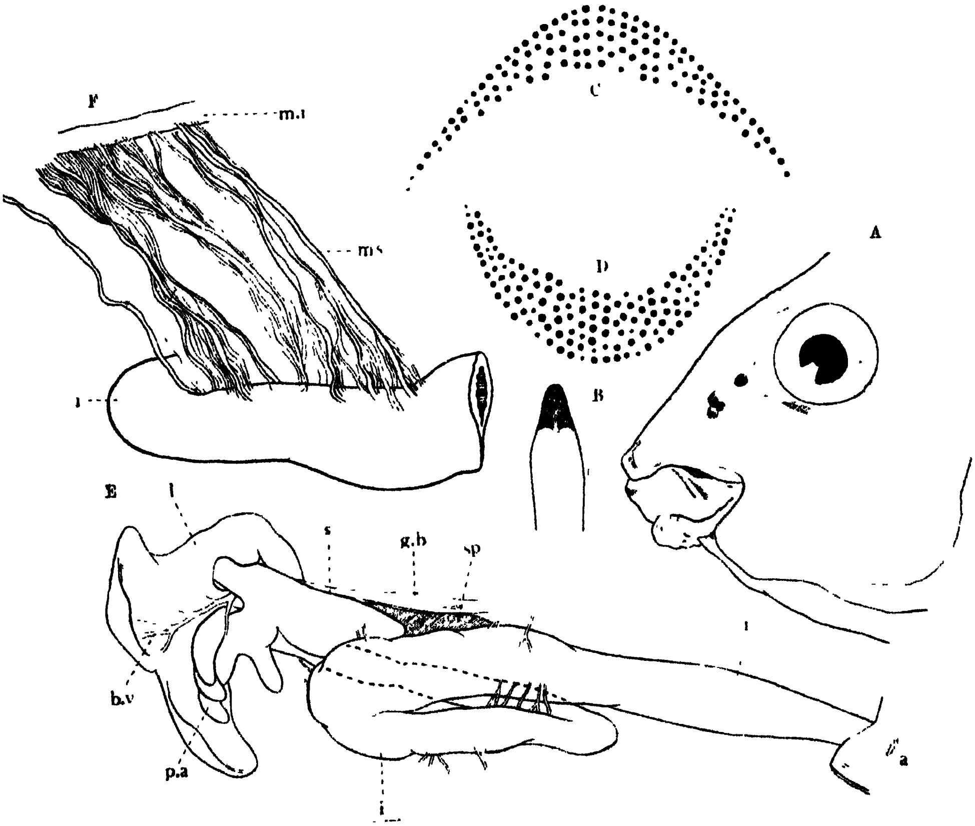


Fig. 124. *Goniistius zonatus*. A. Head. B. Jaw teeth. C., D. Arrangement of upper and lower jaw teeth. E. Digestive tract. F. Mesentery.

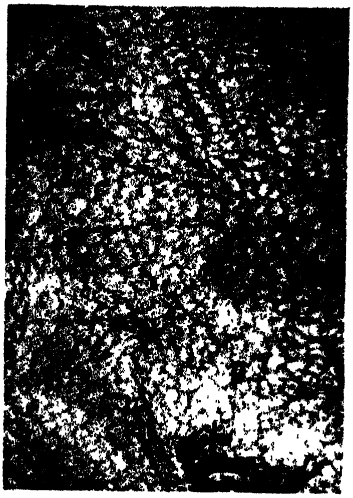


Fig. 125. *Goniistius zonatus.* Folds of mucous membrane of intestine.

Body oblong, compressed. Mouth small (m-c being ca. 1/6, m-b ca. 2/7 of head length), horizontal; lips developed, thick and fleshy. Teeth in each jaw small, conical, closely set in a band; lower jaw has more teeth than the upper. Mouth cavity rather small; no teeth on vomer and platines; palatal mucous membrane red and smooth; tongue small, like the cock's comb, not free. Pharyngeal teeth as large as the jaw teeth. Gill-rakers short (the length being a little shorter than 1/2 of corresponding gill-filaments), stout, tips rather pointed, 22 in number.

Peritoneal cavity large; peritoneum black. Oesophagus short and narrow; stomach small Y-shape (blind sac long, pyloric part short); mucous membrane of the cardiac part consists merely of 4 to 5 parallel longitudinal folds, while that of the blind sac consist of longitudinal folds and transversal folds between those folds. Intestine not long,

Table 28

Stomach contents of *Goniistius zonatus*

Date		Aug. 10, 1933	Nov. 8, 1934	Jan. 30, 1935	Frequency
Locality		"	Mito, Sizuoka Pref.	Misaki, Kanagawa Pref.	
Number of fish		12	15	15	
Stomach contents	Body length (cm)	27.0 ~28.7	27.0 ~28.0	26.5 ~27.7	
Ophiuroidea	Certain sp$_1$		5	2	7
	Certain sp$_2$	1			1
Ostreacea	Usuyukimino (*Hians hirasei*)		9	4	13
	Certain spp.	1	3	2	6
Nudibranchia	Certain spp.	1		1	2
Macrura	*Crago* sp.	3	1	8	12
Brachyura	*Ebalia* sp.			4	4
Amphipoda	Certain spp$_1$	2	5	6	13
	Certain spp$_2$		4		4
Polychaeta	*Nereis* sp.	1	1		2
	Glycera sp.	4	5	10	19
Miscellaneous	Sand particles, fish eyes, straw, etc.	8			8
None		1		1	2

rather wide, winds twice, forming the letter N, mucous membrane net-work; middle intestine distinguished from rectum by the thickness of their walls, viz., the wall of the former thin, while the latter thick. Mesentery well developed along the middle intestine. Pyloric appendages short and wide, 4 in number.

Liver moderately large, polylobes, covering the stomach from above. Gall-bladder long and slender, stretching on the right side of stomach. Pancreas densely distributed on the mesentery and the other parts.

B. Feeding Habits.

As shown in Table 28, I collected 42 fishes from 3 different localities in 3 different seasons.

It is clear from the table that this fish is the bottom feeder. And it is also probable that it takes the creatures in the sandy bottom, such as clam-worms, and hard substances, such as shell-fishes, by using its developed lips, jaw-teeth, and pharyngeal teeth.

94. *Ditrema temmincki* (Bleeker): Umitanago.

A. Digestive System.

Body ovate, compressed. Mouth small (m-c being ca. 2/9 and m-b ca. 1/3 of head length), protrusile; maxillary almost equal to snout; lips thick; teeth conical, tips blunt, in a single series, on the front of the lower jaw only. Mouth cavity small; no teeth on vomer and palatines; tongue rather large, triangular, free anteriorly, no teeth and melanin chromatophores on the surface. Lower pharyngeal bones united, on the surface of which blunt teeth grow pavement-like (Pl. II, Fig. 1). Gill-rakers short (the length being ca. 1/5 of corresponding gill-filaments), tips pointed, coarse, 18 to 20 in number, process on each gill-raker short but numerous.

Peritoneal cavity large and compressed; melanin chromatophores scattered quite profusely on the peritoneum. Oesophagus rather long; no stomach; succeeding the oesophagus is the intestine, rather wide and moderately long (the length being ca. 4 times o~a), winds 3 times approximately 360° and at the rectum approximately 90°, wall rather thick, mucous membrane consisting of typical longitudinal zigzag folds (Pl. XI, Fig. 6). Anus opens between the pectoral and anal fins. No pyloric appendages.

Liver consists almost entirely of the left lobe, the right being only rudimentary and lifts the anterior part of intestine from below; gall-bladder rather long, located between the left lobe and the oesophagus; hepatic artery rather broad. This species is a well known viviporous fish and therefore has an oviduct. It is located between the first and second windings of the intestine, and when it conceives, the oviduct becomes enlarged and pressure is brought to bear on both sides of the intestine. Air-bladder large.

B. Feeding Habits.

This fish seems to feed principally on small animals at muddy bottom, such as the shell-fishes and clam-worms etc., and *Caprella kröyeri* found on sea-weeds and, at times, the sea-weeds themselves. *Caprella kröyeri*, it would seem, is a favorite food for this fish. Kinosita (1930, 1934) reported that abalones and other shell-fishes were found in the stomach of this fish. (As

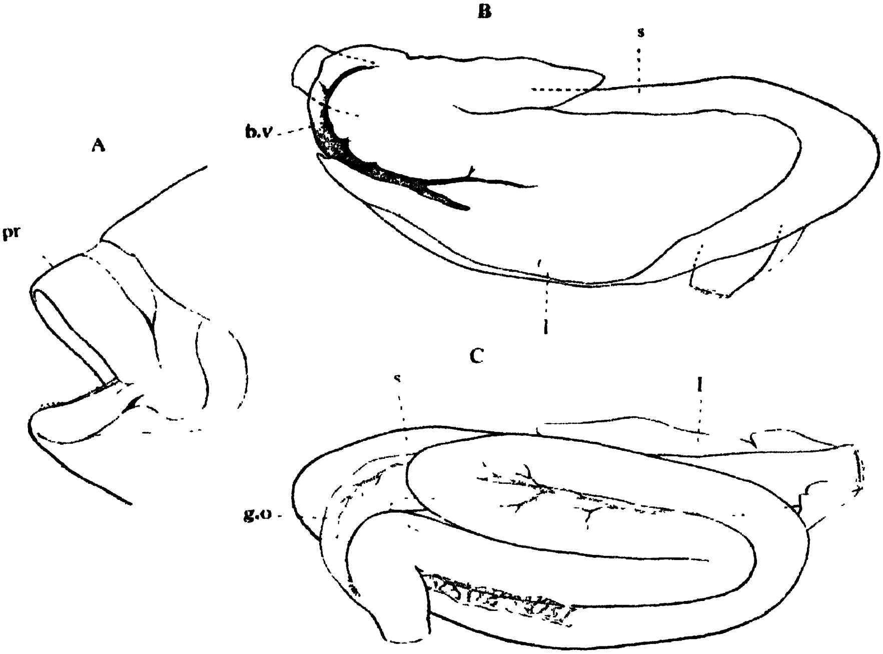


Fig. 126. *Ditrema temmincki*. A. Mouth. B Left side of digestive tract. C Right side of digestive tract

Table 29

Stomach contents of *Ditrema temmincki*

Date	June 28, 1932		Nov. 4, 1934		June, 1936	May 18, 1937		Frequency
Locality	Misaki, Kanagawa Pref.		Mito, Sizuoka Pref.		Ogôri, Yamaguti Pref.	Yokosuka, Kanagawa Pref.		
Number of fish	♂ 5	♀ 5	♂ 14	♀ 2	♂ 20	♂ 14	♀ 12	
Body length (cm)	Av. 19.1	Av. 19.0	12.6 ~17.0	13.3, 16.0	6.6 ~16.3	9.1 ~12.5	9.6 ~14.7	
Stomach contents								
Warekara (*Caprella kröyeri*)	4	3			8			15
Isopoda			12	1				13
Gammarus	2							2
Cladocera			2					2
Shell-fishes					2			2
Clam-worms						5		5
Sea-weeds					4	3		7
Tengusa (*Gelidium amansii*)						2		2
Mud			5			2		7
None		2		1	5		7	15

the pharyngeal teeth of this fish are well developed, it is probable that hard substances are taken).

This species, as stated above, is one of the viviporous fishes, and, therefore, perhaps due to the pressure that is brought to bear on the intestine, the female does not take very much food during the spawing season.

Family LABRIDAE

95. *Halichoeres poecilopterus* (Temminck et Schlegel): Kyûsen.

A, Digestive System.

Body elongate, compressed. Snout pointed; mouth rather small (m-c being ca. 2/11, m-b ca. 3/14 of head length), jaws equal. Teeth in a single series laterally, the number about 10+2+2+10 in lower jaw, and numerous +2+2+numerous in the upper; 4 anterior teeth in each jaw large canines and 2 middle ones of the upper large. Mouth cavity not large; no teeth on vomer and palatines; tongue large, trapezoid, thin, free, no teeth and melanin chromatophores on the surface. Pharyngeal teeth molar-like, well developed. Gill-rakers very short, flat, tips pointed, coarsely grown, 14 to 17 in number.

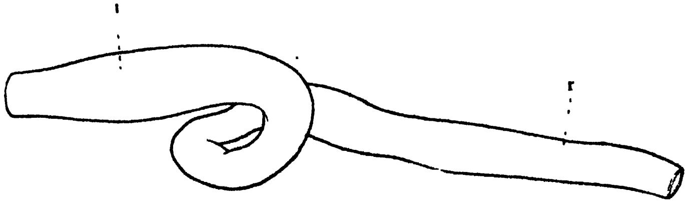


Fig. 127. *Halichoeres poecilopterus.*

Peritoneal cavity rather small; peritoneum silvery. Pharynx wide; oesophagus short and wide, wall thick, mucous membrane consists of about 10 longitudinal folds. Stomach absent; the digestive tract consists merely of the intestine and the rectum. Intestine short (the length of intestine+rectum being ca. 1.3 times o~a), rounded in a small circle; mucous membrane of the intestine consists of papillary processes which arranged in 12 to 13 longitudinal serpentine rows; a valve exists between the intestine and the rectum; mucous membrane of the rectum almost flat. No pyloric appendage.

Liver 2 lobes, left lobe large and the right small, rather thick, lifting the anterior part of intestine from below; gall-bladder ovate, cystic duct rather long. Mesentery developed about the rounded part of intestine.

B. Feeding Habits.

Bigelow and Welsh (1925, p. 283) describe that the cunner (*Tautogolabrus adspersus*) is an omnivorous fish; it finds food browsing among weeds, stones or piles, picking up or biting off barnacles and small blue mussels, with the fragments of which it is often packed full; it devours enormous number of amphipods, shrimps, young lobsters, crabs, ..., univalve and the smaller bivalve mollusks, hydroids, annelid worms, and it occasionally capture small fish.....

Table 30

Stomach contents of *Halichoeres poecilopterus*

Species	*Halichoeres poecilopterus*				*Pseudolabrus japonicus*	
Date	Aug. 12, 1929	Mar. 2, 1930	July, 1936	Aug. 18, 1939	Aug. 13, 1929	May 1937
Locality	Misaki, Kanagawa Pref.	Kotubo, Kanagawa Pref.	Tokonami, Yamaguti Pref.	Horie, Ehime Pref.	Misaki, Kanagawa Pref.	Simoda, Sizuoka Pref.
Number of fish	15	12	6	7	10	9
Stomach contents / Body length (cm)	Av. 15.2	—	14.1 ~15.4	—	Av. 17.0	12.5 ~13.5
Bones of fishes	1					
Amphipoda	4	1			5	
Corophium sp.					1	
Isopoda	2				2	
Ligia exotica	3				2	
Crabs	2	2		6	1	4
Kinsengani (*Matuta* sp.)			1			
Shrimps			3	2	1	
Spirontocaris sp.	1					
Shell-fishes	4			1	2	
Yamakisago (*Waldemaria japonica*)	1					
Kamenote (*Mitella mitella*)					1	
Eggs of Amefurasi (*Aplysia punctata*)	2					
Polychaeta		1	2	2		
Eunice kobiensis	1					
Nereis			1		1	5
Tube of clam-worms						2
Sea-weeds (*Ulva*, etc.)	3			2		
Sand particles		2		2	1	
None	1	8				1

I examined 40 stomachs, as shown in the table, and found that this fish is also omnivorous as in the case of the cunner. In connection with the feeding habits of this fish, I must also mention that in the majority of cases, at night or in winter it creeps into the sand at the bottom of the sea and does not take any food, as it sleeps everv night in the sand. S. Miyauti (1936, p. 34) made a very interesting report on this.

96. *Pseudolabrus japonicus* (Houttuyn) : Sasanohabera.

A. Digestive System.

The form of the digestive system of this fish is almost the same as that of the above-mentioned fish, and the difference between the two as follows: — 3 anterior teeth in each jaw large (Pl. I, Fig. 7); tongue a little larger than that of the above species; anterior part of the intestine rather wide.

B. Feeding Habits,

There is not much difference in the feeding habits of this fish and the preceding one.

Family CALLYODONTIDAE (SCARIDAE)

97. *Leptoscarus japonicus* (Cuvier et Valenciennes): Budai.

A. Digestive System.

Body oblong, moderately compressed; head short, rather blunt. Mouth rather wide (m-c being ca. 2/11, m-b ca. 1/2 of head length); jaws equal. Teeth moderately large, about equal in size, separate, those in anterior half of jaws arranged in series of oblique rows (Pl. I, Fig. 9) Mouth cavity more or less depressed. Tongue large, semi-circular, rather soft, free marginally, no teeth and melanin chromatophores on the surface. Pharyngeal teeth very characteristic, large, tessellated, the upper being 2 sets and the lower 1. Gill-

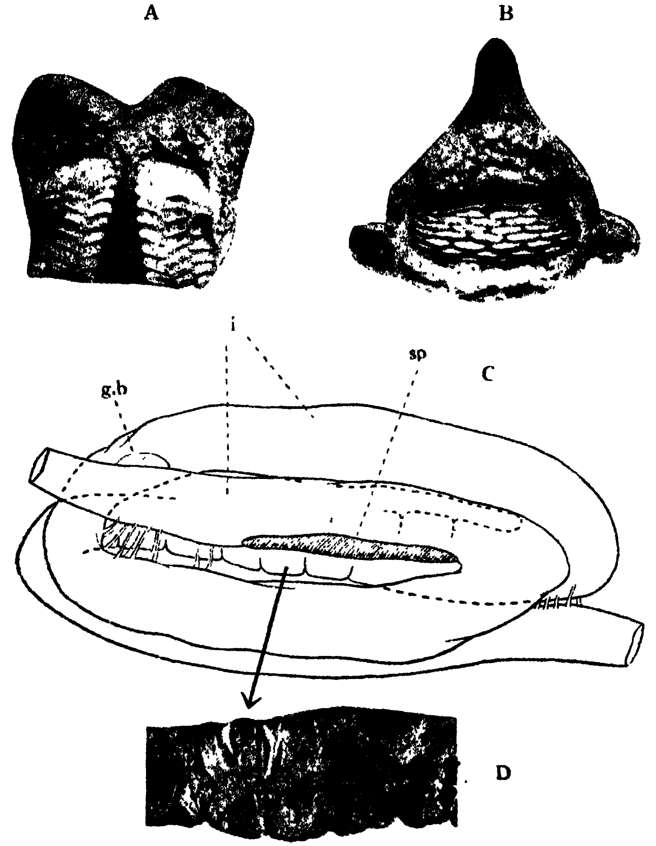


Fig. 128. *Leptoscarus japonicus*. A. Upper pharyngeal teeth. B. Lower pharyngeal teeth. C. Digestive tract. D. Notched intestine.

rakers short, rather soft, tips pointed, coarsely grown, 10 to 14 in number.

Peritoneal cavity large, ovate; peritoneum brown. Stomach absent. Intestine long (the length being ca. 5.5 times o~a), winds 4 times; middle intestine notched as shown in the figure, wall very thin, mucous membrane consists of small papillary processes arranged net-work. Rectum short, wall rather thick; a valve located between the middle intestine and the rectum. No pyloric appendage.

Liver large, 2 lobes, left lobe large while the right very small; gall-bladder rather large, spherical. Mesentery very well developed. Spleen slender, located near the anterior part of intestine. Air-bladder elongate, silvery, wall rather thick.

B. Feeding Habits.

In the March 6, 1938 issue of the Sandei Mainiti, p. 19. there is an article on the feeding habits of this fish by Mr. Tademura. In early spring, according to this article, this fish flocks along the rocky coast of rough sea and eagerly eats the shoots of sea-weeds.

On November 7, 1938 and October 2, 1939, I bought some of this fish from the Tokyo Fish Market (8 in all, with a body length of about 25 cm), and on examination, they had eaten a stomachful of sea-weeds. Boulenger (1922, p. 674) writes: "Parrot-wrasses feed mostly on vegetable matter, corals, and hard-shelled Mollusca, for crushing which their dentition is well adapted."

Family CHAETODONTIDAE

98. *Chaetodon modestus* (Temminck et Schlegel): Genrokudai.

A. Digestive System.

Body short, very much compressed. Head small, with very steep but slightly concaved profile. Mouth small (m-c being ca. 1/6 and m-b ca. 1/8 of head length). 11 rows of slender, soft teeth in the upper jaw and 8 rows in the lower (similar to the jaw teeth of the lizard fish), arranged in the form of arches. Mouth cavity compressed; no teeth on vomer and palatines; tongue large and triangular, thinning out as it comes to the end, free anteriorly, grooved in the center, no teeth. Minute soft teeth on the pharyngeal bones. Gill-rakers short (the length being ca. 1/4 of corresponding gill-filaments), flat, tips pointed, grow apart, about 18 in number, 2 rows of process on each gill-raker.

Peritoneal cavity compressed, lens-shape: peritoneum silvery grey. Oesophagus long. Stomach Y-shape, ambiguous to V-shape; cardiac part long and narrow; pyloric part spherical and rather large; wall of stomach thick; mucous membrane 8 longitudinal folds, with small warts between the folds. Intestine long (the length being ca. 7 times d~a), the winding of the first half of it clockwise while the latter half counter-clockwise, wall thin, rather wide, mucous membrane longitudinal folds. Pyloric appendages rather long and broad, 1 of the 5 being short.

Liver moderately large, rather thick, 2 lobes, the left being larger than

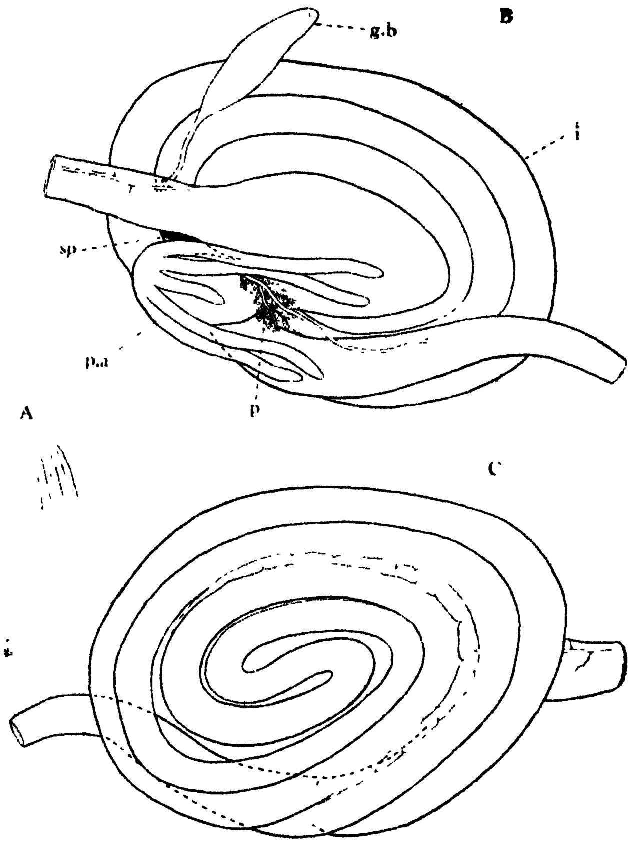


Fig. 129. *Chaetodon modestus.* A. Jaw-teeth. B. Left side view of digestive tract. C. Right side view of the same.

the right. Gall-bladder ellipsoid. Spleen small. Pancreas fills up the space made by intestinal windings in vortex form.

B. Feeding Habits.

From the very few samples which I was able to examine, it would seem that the usual food of this fish is hermit-crabs and sea-weeds, but I cannot say anything definite. The divers say that this fish, not only this species but all those that belong to Chaetodontidae and which have this sort of body form, lies laying horizontally its body when it eats the food on rocks.

Family SIGANIDAE

99. *Siganus fuscescens* (Houttuyn): Aigo.

Body compressed, oblong. Head small. Mouth small (m-c being ca. 1/16 of head length and m-b being a little larger than this), slightly inferior; mandible not projecting, with the lower jaw fitting under the upper; lips rather broad; a series of 25 to 30 small conical teeth in each jaw, roots deeply buried, and against the row of teeth inside there is a membrane. No teeth on vomer and palatines. Buccal cavity large; Plicae palatinae well developed; tongue moderately large, rectangular, soft, free, sides somewhat high making a groove in the center, surface smooth except for a few papillae; no melanin chromatophores. Gill-rakers characteristic: tips branch out as shown in Fig. 130, B, pointed and short (ca. 1/10 of corresponding gill-filaments), grown apart, 20 in number. Upper pharyngeal teeth well developed, consisting of 3 sets of small conical teeth in groups.

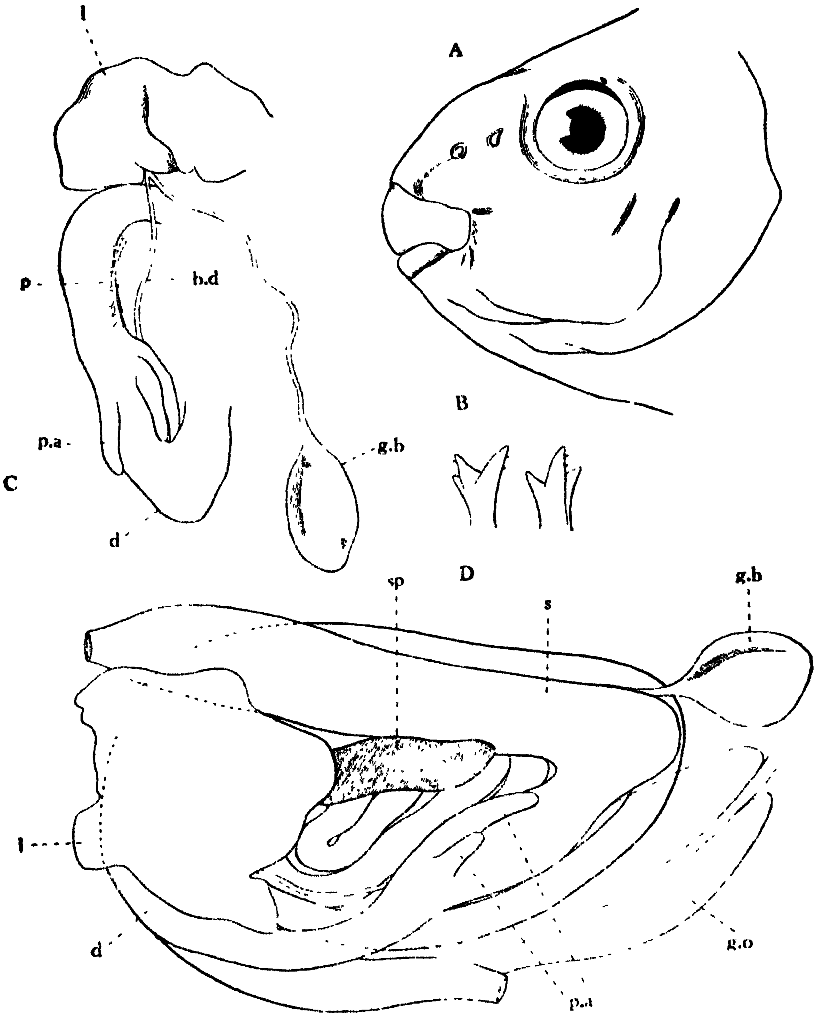


Fig. 130. *Siganus fuscescens.* A. Head. B. Gill-rakers. C. Digestive tract. D. Gall-bladder.

Peritoneal cavity compressed but large; oesophagus short. Stomach medium size, V-shape; cardiac part long, being approximately twice as long as the pyloric part; blind sac rudimentary and rounded. Wall of stomach thick, and the mucous membranes of the cardiac and pyloric parts and the blind sac consist respectively of approximately 12 narrow longitudinal folds, 12 wide longitudinal folds, and a net-work of squares. Epithelium of the pyloric part somewhat chitinous. A pyloric valve divides the stomach and the duodenum (Fig. 131). As may be seen from the figure, while the folds of the mucous membrane of the pyloric part are longitudinal, those of the duodenum are like the face of a towel. Intestine rather broad, extremely long (the length being ca. 2.5 to 3 times the body length and ca. 8 times d$\overset{\cdot}{\sim}$a), winding very characteristic, that is, it first winds clockwise, like a vortex, to the body lengthwise, and when it comes to the center, it reverses and goes counter-clockwise, forming, as it were, 2 vortices put together, one running clockwise and the other counter-clockwise. Wall of intestine thick. The anus opens just in front of the anal fin, the peritoneal cavity stretching trifly beyond the anus. Pyloric appendages 3, rather thick and round, 1 being short and the other 2 long.

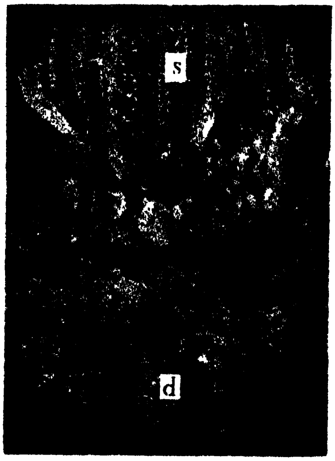


Fig. 131. *Siganus fuscescens.* Stomach and intestine.

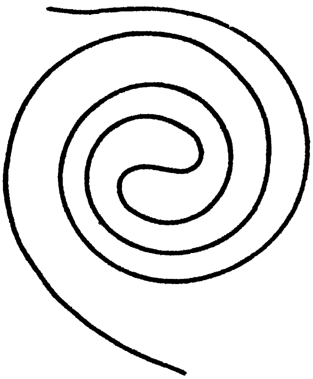


Fig. 132. *Siganus fuscescens.* Intestinal winding-type.

Liver rather small, the left lobe being tolerably large and the right long but small. Gall-bladder spherical; Ductus choledochus and Ductus cystis both extremely long. Pancreas well developed along the stomach and intestine. When the gonad is fully developed, it pressess the intestine to the ventral side.

B. Feeding Habits.

As for the feeding habits of this fish, Uchida (1932) took this up as a part of his study when he was studying its general habits. He said that the larvae of this fish about 14 cm in body length fed chiefly on copepods; those from 18 to 20 cm on diatoms that are found on sea-weeds; and those from about 30 cm on the diatoms above-mentioned and young sea-weeds; and that as they grew older, the herbivorous habit became more pronounced. But at the same time, he stated that as the angling baits of this fish consisted of animal matter, there was, at times, a possibility of their taking animal food.

From my examination of the stomach contents of this fish collected in the summers of 1933 and 1935, I found that they consisted principally of sea-weeds, and that only a very small quantity of animal food could be found. In comparing the feeding habits of this fish with other fishes, there are very few that take so much sea-weed, and to call this species as the "herbivorous fish" would not, in my opinion, be at all unsuitable.

Family TRIACANTHIDAE

100. *Triacanthus brevirostris* (Temminck et Schlegel): Gima.

A. Digestive System.

Body oblong, compressed. Mouth very small (m-c being ca. 1/12 and m-b ca. 1/6 of head length); lips thick; 2 rows of jaw teeth in each jaw, the outer series being incisor-like, rounded at the top. Mouth cavity small; no teeth on vomer and palatines. Tongue large, semi-elliptic, free anteriorly, rather thick, grooved in center, no teeth and melanin chromatophores on the surface. Pharyngeal teeth rudimentary. Gill-rakers very short (the length being ca. 1/10 of corresponding gill-filaments), tips blunt, coarsely growth, 13 to 15 in number.

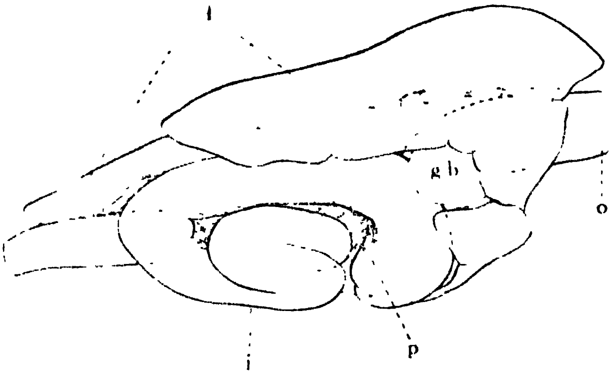


Fig. 133. *Triacanthus brevirostris.*

Peritoneal cavity compressed; some melanin chromatophores on the peritoneum. Oesophagus short, mucous membrane of which consists of 14 to 15 longitudinal folds; stomach S-shape, wall rather thin, mucous membrane of which being longitudinal folds consisting of papillae; intestine rather long (the length being ca. 2.5 times d~a), wall thin, winds in a characteristic manner as shown in the illustration, the end being the rectum. Mucous membrane of the intestine consists of papillary processes. No pyloric appendage.

Liver large, 3 lobes, the largest lobe locates on the left side of the digestive tract, and the smaller 2 lobes on the right. Gall-bladder large, spherical; bile-duct opening to the beginning part of the intestine. Mesentery well developed, along which are the pancreas. Air-bladder large, elongate.

B. Feeding Habits.

I have never had a chance to make a study of the feeding habits of this fish.

Family BALISTIDAE

101. *Canthidermis rotundatus* (Procé): Amimongara.

A. Digestive System.

Body oblong, compressed. Mouth very small (m-c being ca. 1/13 of head length), terminal; lips thick, especially the lower. Jaw teeth large, in a single row, in the majority of cases, 4 in each side, closely set. Mouth cavity small; no teeth on vomer and palatines. Hardly any difference in the tongue in comparison with the above-mentioned species. On the 3 sets of the upper pharyngeal bones, 2 rows of sharp conical teeth which directed inward. Gill-rakers short (the length being ca. 1/6 of corresponding gill-filaments), soft, flattened laterally, tips pointed, coarse, 28–32 in number.

Peritoneal cavity compressed; peritoneum silvery. As the internal organs of the sample which I had handled had self-decomposed and an accurate observation could not be made, I shall not trouble to give the results of my examination. There is a study on the internal organs of *Balistes capriscus* in Meckel's "Systems der vergleichenden Anatomie," Vol. IV, and according to that article, the wall of the stomach is thin; there is no valve between the stomach and intestine; the length of the intestine is a little less than double the body length, it winds 5 times and is divided into the middle intestine and the rectum by a valve; the wall of the former is rather thick but the latter is rather thin. According to Jacobshagen who also made an examination of the same species, the mucous membranes of the stomach and middle intestine (he uses the word "Vorderdarm"), are described as consisting of parallel longitudinal folds and simple net-work respectively. When I made an examination of the subject species, I found that the intestinal mucous membrane of which consisted of papillary processes; the liver had 3 lobes, and the air-bladder was very large.

B. Feeding Habits.

Mr. M. Uda very kindly let me have the 3 fishes (22., 24.1 and 25.3 cm in body length) which he had caught at a certain place while out on the experimental ship of the Imperial Fisheries Experimental Station in the Pacific, in May 1936. The stomach of these were filled with fish bones and shrimps. The fish 28.0 cm in body length, which Mr. S. Miyauti had obtained from the Tokyo Fish Market on the 1st of October 1937 also had its stomach filled with fish-bones.

Family MONACANTHIDAE

102. *Monacanthus cirrhifer* (Temminck et Schlegel): Kawahagi.

I have already made a detailed report on the digestive system and feeding habits of this species.

A. Digestive System.

Body short and deep, very much compressed. Mouth very small (m-c being ca. 1/9 and m-b ca. 1/5 of head length), terminal; lips thick and fleshy. 2 rows of incisor-like teeth in the upper jaw, 6 in the outside row and 4 in the inside row; about 6 incisor-like teeth in a single series in the lower jaw; teeth all very strong and closely set, Mandibularis and Maxillaris, viz. the muscles of jaw, being well developed. Mouth cavity small; no teeth on vomer and palatines; tongue moderately large, rectangular, thick, free anteriorly, smooth, longitudinal folds only on the surface and no melanin chromatiphores. No pharyngeal teeth. Gill-rakers short (the length being not even quite 1/6 corresponding gill-filaments), tips pointed, coaresly grown, 27 in average; process on each gill-raker numerous (Pl. IV, Fig. 4).

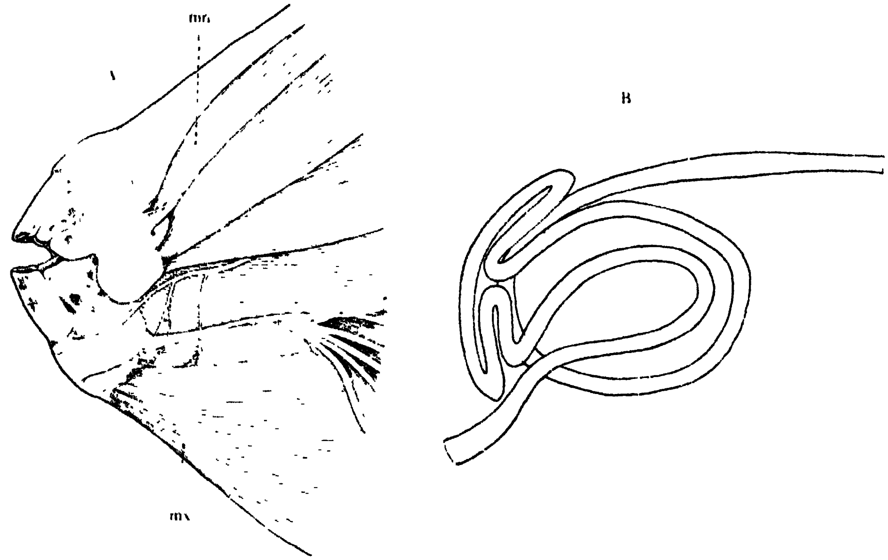


Fig. 134. *Monacanthus cirrhifer*. A. Jaw-teeth and cranial muscle. B. Diagram showing the intestinal winding-type.

Peritoneal cavity compressed; no melanin chromatophores on the peritoneum. Stomach short, being a straight tube, wall thin, folds of the mucous membrane longitudinal. Intestine rather long (the length being ca. 2.5 times d~a), wall thin, winds as the illustration, this type of winding being common to the flat-fish, which is worthy of note; mucous membrane consisting of papillary processes. The stomach and intestine may be distinguished according to their mucous membranes. The end of the intestine is the rectum. No pyloric appendage.

Liver very large, 2 lobes, the left lobe being very much larger than the right. Gall-bladder located between the gonad and the end of the right-lobe. Cystic duct rather long. Intestinal tube is kept in place by a well developed mesentery.

B. Feeding Habits.

Regarding the feeding habits of *Monacanthus*, there are 2 publications written by Brehm (1914, p. 432) and Boulenger (1922, p. 624) who recognized the European *Monacanthus* as herbivorous fish, but Uchida (1927) denied their view when he studied Japanese

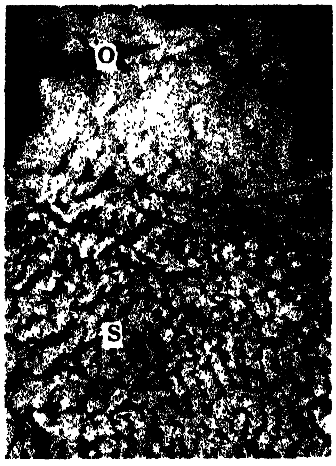


Fig. 135. *Monacanthus cirrhifer.* Folds of mucous membranes of oesophagus and stomach.

Table 31

Stomach contents of *Monacanthus cirrhifer*

Date	Sept. 3, 1932	June 7, 1933	Jan. 10, 1934	Frequency
Locality	Misaki, Kanagawa Pref.	Katuura, Tiba Pref.	Misaki, Kanagawa Pref.	
Number of fish	40	15	15	
♀ : ♂	21:19	8:7	10:5	
Av. body length(cm) / Stomach contents	14.9	14.6	13.8	
Certain fishes — bones, eyes	3			3
Isopoda	1		2	3
Amphipoda			8	8
Paguridae	8		5	13
Warekara (*Caprella kroyeri*)		3		3
Balanus sp.	5	1		6
Plecypoda	1			1
Placopoda	4	2		6
Platypoda	4			4
Lepas sp.		2		2
Nereis sp.			2	2
Echinometra sp.	4			4
Fragment of a stone-coral (*Anisopamma amphelioides*)	1			1
Sargassum sp.	1			1
Sea-weeds		3		3
Sand-stones	11			11
Sand particles, etc.			12	12
Indistinct	14	5	3	22
None				0

Monacanthus. Uchida says that fishes 8 to 18 mm in body length feed on *Globigerina*, Copepoda, zoëa, while those 21 to 29 mm long on zoëa, *Gammarus*, diatoms, and brown algae. For comparison, I analysed, as shown in the Table 31, the stomach contents of adult fishes, 11.3 to 17 cm in body length, collected on 3 different occasions, at 2 different places, and at differnt seasons. From the results obtained, I am inclined to think that while this fish lives near the coast in summer, in winter it moves more out to the sea and hovers near the bottom in search of food. The bones and eyes of fishes found among the stomach contents were perhaps those of dead fishes, for it is hard to believe that it would attack live ones. And when *Caprella kröyeri* and seaweeds, *Gammarus* and sand particles, were found together in the stomaches at the same time, I was inclined to believe that in each instance, the latter was swallowed in its efforts to eat the former. The fact that a fragment of *Anisopamma amphelioides* was found in the stomach may perhaps be considered as a good evidence that this fish can bite off by using its stout teeth the hard substances on rock.

Family OSTRACIIDAE

103. *Aracana aculeata* (Houttyn) : Itomakihugu.

A. Digestive System.

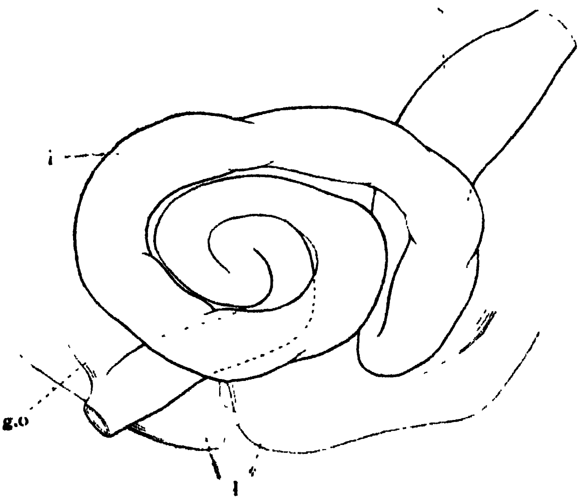


Fig. 136. *Aracana aculeata.*

Fig. 137. *Aracana aculeata.* Folds of intestinal mucous membrane.

Body short, slightly compressed, stout, covered by hard and immovable carapace. Mouth very small (m-c being ca. 1/7, m-b ca. 3/10 of head length) ; lips thick, fleshy. Teeth in each jaw subequal, 8 to 9 in number, arranged in a row, rather large, not incisor-like, rather conical, tips blunt, the base brown. Mouth cavity very small; no teeth on vomer and palatines. Tongue moderately large, semi-elliptic, thick, soft and fleshy, not free, no teeth and melanin chromatophores on the surface. Pharyngeal teeth and gill-rakers both absent.

Peritoneal cavity large; no melanin chromatophores on peritoneum. Oesophagus short and rather narrow, wall thick, mucous membrane consists of 24 to 26 longitudinal folds. Stomach merely a cylindrical tube, wall rather thin, mucous membrane consists of 14 longitudinal serpentine folds. Bounded by a valve, intestine succeeds the stomach. Intestine rather long (the length of stomach plus intestine being ca. thrice o~a), winds vortically as shown in the figure, wall thin, mucous membrane consists of transversal papillary processes. No pyloric appendage.

Liver large. 2 lobes, left lobe very much larger than the right, thick; gall-bladder spherical, rather large, located on the upper part of the intestine. Spleen small, situated on the left of stomach.

B. Feeding Habits.

This fish takes usually the small animals in the muddy bottom of the sea.

Family TETRAODONTIDAE

104. *Sphaeroides rubripes* (Temminck et Schlegel): Torahugu.

A. Digestive System.

As the digestive system of this fish is almost the same as the following species (No. 105), I shall omit its description.

B. Feeding Habits.

From my examination of the stomach contents of 16 adults which Mr. J. Deguti collected on May 3, 1937 near the Misaki Marine Biological Station, the 12 (average body length: 12.6 cm), Mr. S. Miyauti collected at Yokosuka, Kanagawa Prefecture, and the 10 (body length: ca. 10 cm) collected by Mr. H. Tokunaga on September 15th, 1938 at Kasaoka, Okayama Prefecture, I am of the opinion that this species is definitely an omnivorous fish, and that it feeds on small fishes, crabs, rock-slaters, sea-weeds, and other small animals which cling to rocks, etc.

Fig. 138. *Sphaeroides rubripes.* Folds of intestinal mucous membrane.

105. *Sphaeroides vermicularis* (Temminck et Schlegel): Syôsaihugu.

A. Digestive System.

Body elongate, slightly compressed. Head long, rather compressed. Mouth small (m-c being ca. 1/4 of head length), terminal, crescent as viewed from the front. Jaw teeth large, rather pointed anteriorly, cutting edges slightly concave. Mouth cavity moderately large; no teeth on vomer and palatines. As for the muscles inside the mouth, Mandibularis of the adductor mandibulae is well developed but not Maxillaris of the adductor mundibulae. Tongue large, semi-elliptic, thick, not free, no melanin chromatiphores on the surface but the longitudinal folds of the mucous membrane are conspicuous. No pharyngeal teeth. Gill-rakers rudimentary, and generally 8 in number.

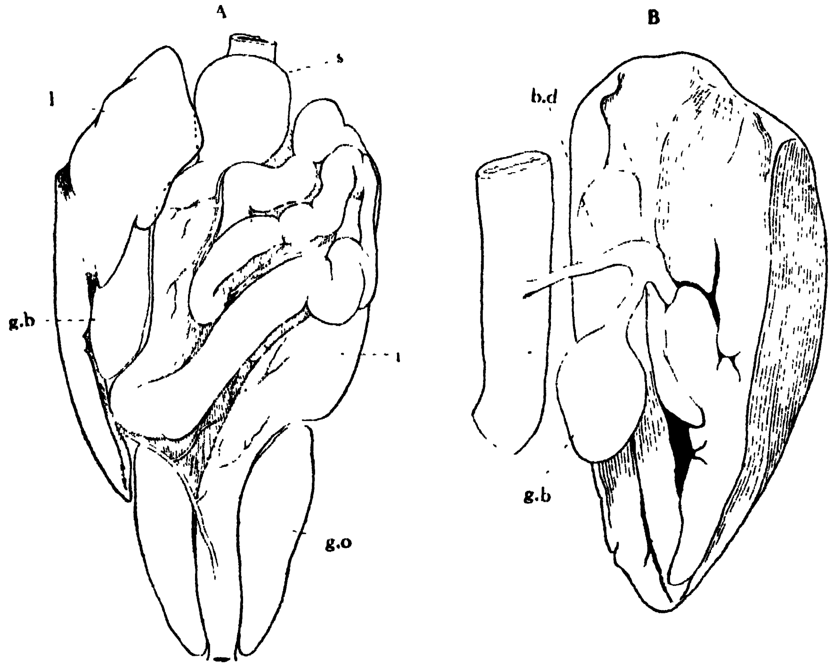


Fig. 139. *Sphaeroides vermicularis*. A. Digestive tract. Ventral side. B. Liver with gall-bladder.

Peritoneal cavity large; no melanin chromatophores on the peritoneum. Oesophagus wide at the beginning, narrowing as it gets toward the stomach; stomach short and round, constricting at the end on both sides, becomes the intestine, mucous membrane 20 to 22 longitudinal folds. Intestine rather long and wide (the length being ca. 3.2 times d~a), makes 6 long and several short turns, wall rather thick. mucous membrane consisting of papillae along the longitudinal zigzag folds. Bile duct opens at the beginning of the intestine, i. e., duodenum. Intestine held in place by a very well developed mesentery.

Liver very large, 1 lobe, thick, located on the right side of the digestive tract; gall-bladder large, almost spherical; length of the cystic and hepatic ducts about the same.

Cuvier (1810, Vol. 3) examined the digestive tract of *Tetrodon oblongus* and described the stomach as being round, the intestine as being short and winding 2 or 3 times, and the wall as being thick.

B. Feeding Habits.

In the report made by Bigelow and Welsh (1925, p. 299), they write as follows on the feeding habits of *Spheroides maculatus*; " Puffers are summer fish on the southern New England coast, appearing late in May or early in June, to disappear in October or November. They are rarely seen far from land, usually in water only a few fathoms deep, where they feed on small crustaceans of all sorts, especially crabs, shrimp, and amphipods, as well as on small mollusks, worms, barnacles, sea-urchins and other invertebrates, which they find on bottom."

Family MOLIDAE

106. *Mola mola* (Linné): Manbô.

A. Digestive System.

Form of body varies considerably with age, adult disc-form and the longitudinal diameter of which being slightly longer than vertical. Mouth very small (m-b ca. 1/20 of body length), horizontal; lips moderately thick; incisor-like teeth in upper and lower jaws, cutting edges concave, the groove between the teeth scarcely perceptible, the upper middle tooth fairly long, and bluntly pointed. No teeth on vomer nor palatines. Buccal cavity large, compressed sidewise; mucous membrane of oral cavity pigmentless; Plica palatinae not developed. Tongue large, semi-elliptic, thick, not free, soft and smooth, brown pigments scattered on the surface. 6 to 8 pharyngeal teeth in a row on each front, middle, and back sets of upper pharyngeal bones, extremely sharp and long, curve slightly in. Gill-rakers skinny filaments, short, (ca. 1/5 of corresponding gill-filaments), about 30 in number, grow coarsely, vertical to the gill-arch, tips not pointed, no process. Pharynx wide.

Peritoneal cavity large; peritonium with no melanin chromatophores. Oesophagus thick but narrow in comparison with the part succeeding it, walls thick, not very long, mucous membrane assuming 6 wide longitudinal folds. Stomach absent; oesophagus succeeding the duodenum. This may be identified histologically but it may also be identified by the fact that the Ductus choledochus opens at this place. Duodenum exceptionally broad, wall thick, mucous membrane consisting of small villi and making its appearance the face of a towel. Intestine 1.5 times the width of the duodenum, long, making approximately 15 turnings in all directions, walls thick, mucous membrane of which not differing very much from that of the duodenum. Succeeding the middle intestine is the rather long rectum, the width, and the thickness of the walls exactly the same as the former. Outwardly there is no difference between the two parts; however, the former is clearly distinguished from the latter by the inner valve, the folds of the mucous membrane likewise. Total length of the intestine, i. e. duodenum plus middle intestine plus rectum, about 3.2 times as long as the body length and approximately 8 times as long as o~a; rectum about 1/16 of the total length. Mesentery well developed. Pyloric appendage absent.

Regarding the digestive tract of this fish, Cuvier (1809) called the part which I identified as the duodenum the stomach, and Meckel (1829) said that the intestine, which is 5 times as long as the body length, made very short

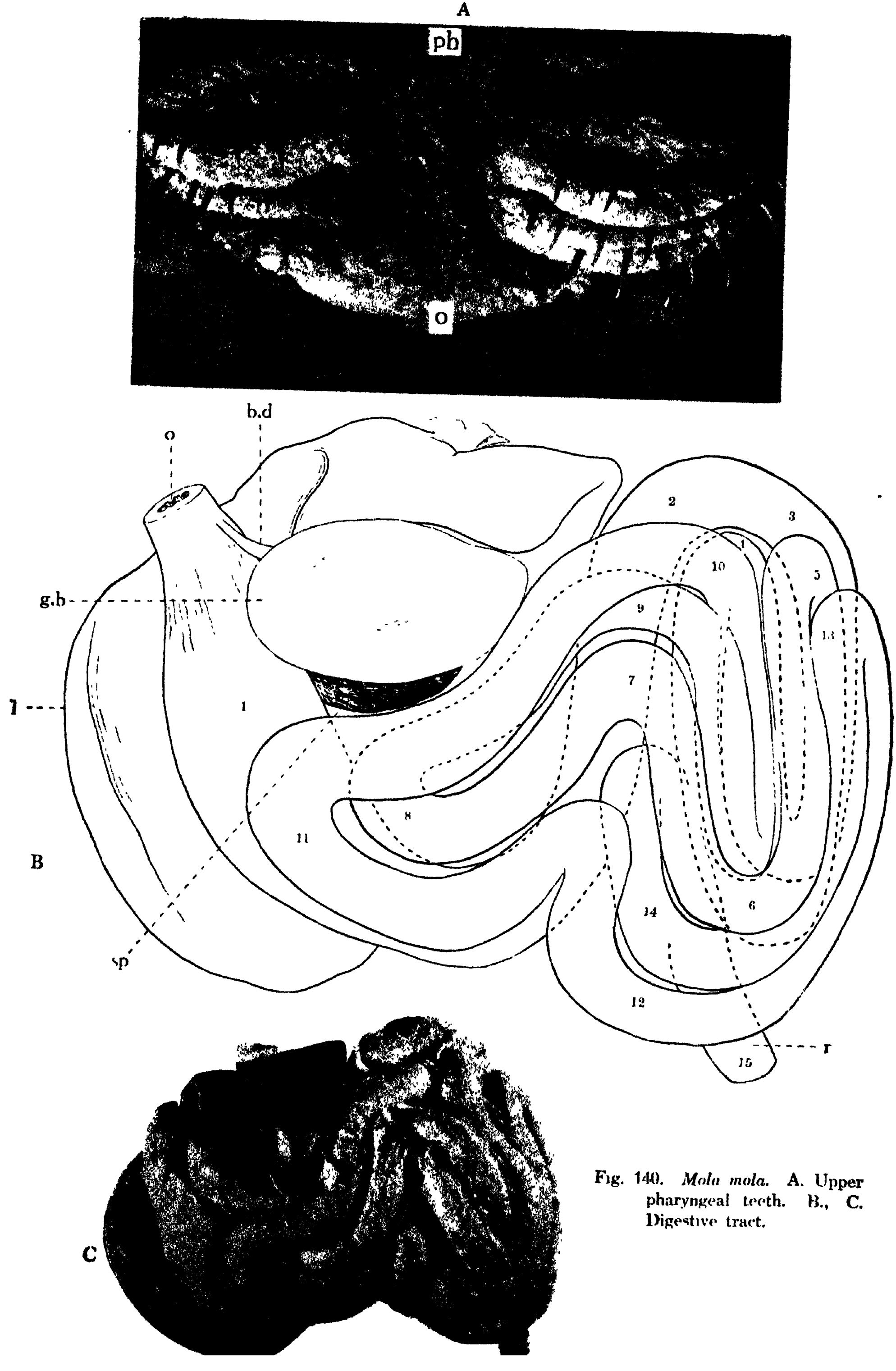


Fig. 140. *Mola mola.* A. Upper pharyngeal teeth. B., C. Digestive tract.

turnings, and that the Ductus choledochus began 1.5 inches from the mouth. He said that the mucous membrane of the stomach (so called by him) formed longitudinal folds, and that there were villi on the intestine.

Liver consists of 1 large lobe, situated at the right side of the digestive tract, thicker and rounder than that of *Monacanthus cirrhifer*, bright yellow when fresh. Gall-bladder large, almost spherical. Ductus choledochus short, opens to the beginning of the duodenum where it succeeds the oesophagus. It is to be noted that the Ductus choledochus near the part that opens assumes a muscular nature, the tube becoming very large. Spleen situated near the gall-bladder; liver large, almost spherical. Air-bladder large, walls rather thick.

B. Feeding Habits.

The body of this fish is not only peculiarly formed but it also has very curious feeding habits. It is an already well known fact that it feeds on jelly-fish. Boulenger (1922) describes it on page 727 of his book: "Its food is said to consist chiefly of jelly-fish······".

Table 32

Date	Locality	Collector	Body length (cm)	Body weight (kg)	Stomach contents
July, 1928	Misaki Fish Market	—	—	—	Jelly-fishes
June 16, 1935	Near Smith Island	Fuzi Maru	105	—	Jelly-fishes
July 29, 1935	Off the coast of Kinkazan	Sôyô Maru	88	—	Feathers of bird
Feb. 23, 1939	34° 12′ N 140° 06′ E	Sôyô, Maru	200	ca. 225	Jelly-fishes

As shown in the Table 32, I collected one each of this fish from 4 different localities around Japanese waters, and found, on examination of their stomach contents, that 3 out of 4 had eaten a stomachful of jelly-fish. There is therefore, no doubt but what this fish takes jelly-fish for its staple food. It seems fitting and proper that a dull-looking fish such as this should make jelly-fish its chief food. I would also say that the unusual pharyngeal teeth of this fish has much to do with its feeding habits.

Family SCORPAENIDAE

107. *Sebastodes inermis* (Cuvier et Valenciennes): Mebaru.

A. Digestive System.

Body oblong, more or less compressed; head pointed. Mouth moderately large (m-c being ca. 2/5, m-b ca. 3/8 of head length); lower jaw longer than the upper. Teeth in each jaw minute, conical, in narrow band, developed in a knob at the tip of lower jaw. Mouth cavity moderately large; palatines armed with teeth; tongue large, triangular, free, black and yellow pigments on the surface (Pl. III, Fig. 6). Pharyngeal teeth as large as jaw teeth, closely set on pharyngeal bones. Gill-rakers long (slightly shorter than corresponding gill-filaments), tips rather blunt, closely set, 24 to 29 in number.

Peritoneal cavity rather large; no melanin chromatophores on peritoneum. Oesophagus broad and rather long. Stomach medium in size, ┐-shape, wall thick, cardiac part longer than blind sac, and pyloric part the shortest. Mucous membrane of stomach with longitudinal serpentine folds. Intestine fairly long (the length being ca. 3.2 times d∼a), winds 4 times, wall rather thin, folds of mucous membrane net-work. Wall of rectum comparatively thick. Pyloric appendages rather wide and moderately long, located at the left side of stomach, 10 in number.

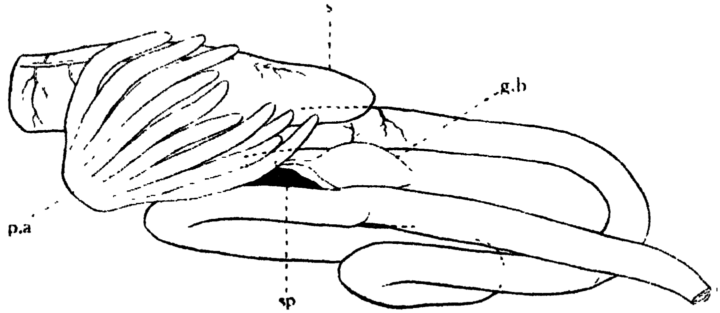


Fig. 141. *Sebastodes inermis.*

Liver large, 2 lobes, left lobe longer than the right, lifting the stomach and pyloric appendages from below. Gall-bladder short, ellipsoidal, moderately large; cystic duct long. Air-bladder large but not so large as the following species, wall thick.

Eggeling (1908) anatomizes the digestive tract of *Sebastes dactyloptera* and reports that this fish has large blind sac and 7 pyloric appendages.

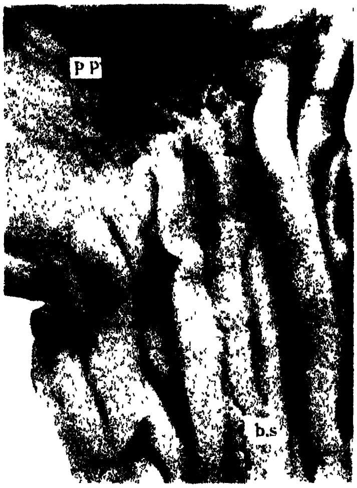


Fig. 142. *Sebastodes inermis.* Folds of mucous membranes of pyloric part and blind sac.

B. Feeding Habits.

Through the courtesy of Mr. H. Higasi, I examined the stomach contents of 9 of this species (14.5 to 22.0 cm in body length) caught from the adjacent waters of Makuhari, Tiba Pref., on May 19, 1936, when I found that 7 of them had eaten Megalopa larvae of Syôzingani (*Plagusia dentipes*) (each one having eaten 10 in average). 2 had empty stomachs. 31 adults (10.1 to 14.8 cm in body length) collected in July of the same year had eaten mostly Isopoda and *Mysis*, while the 39 young fishes (3.9 to 5.7 cm in body length) had taken *Mysis* for their principal food. Judging from these results, it would seem that this fish is not a bottom feeder but feeds principally on food found in the middle and upper layers of the sea and has its habitat among the sea-weeds of shallow water.

108. *Sebastodes flammeus* (Jordan et Starks): Sankômenuke.

A. Digestive System.

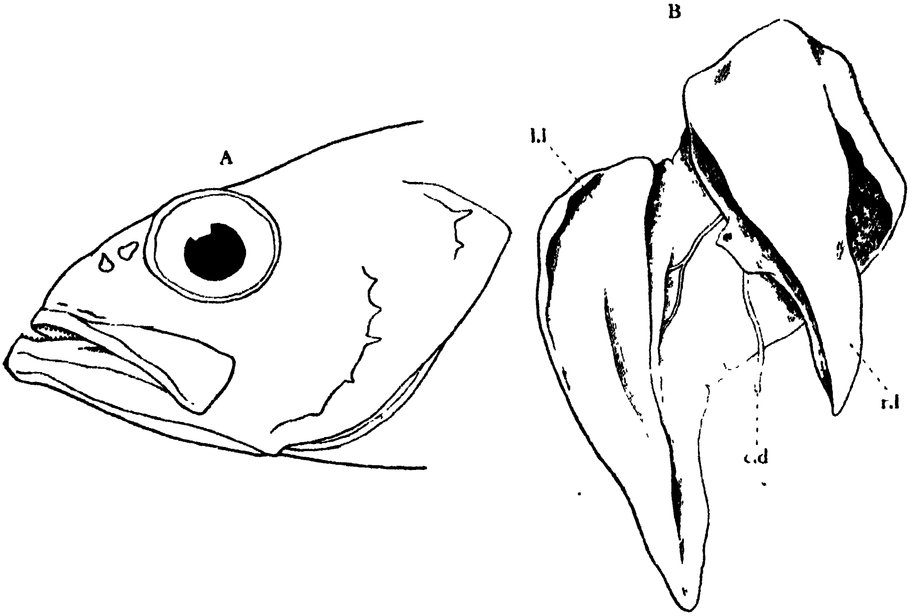


Fig. 143. *Sebastodes flammeus*. A. Head. B. Liver.

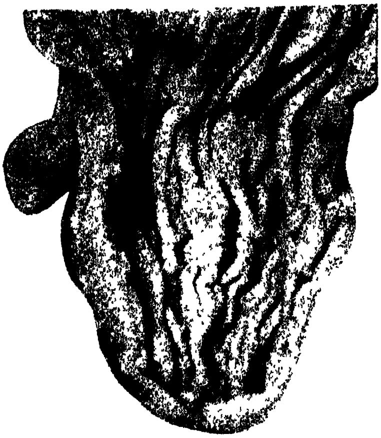


Fig. 144. *Sebastodes flammeus*. Folds of mucous membrane of stomach.

As the digestive system of this fish has a much resemblance to that of the above species, in order to avoid duplication, I shall give a description of only its outstanding characteristics.

The jaw teeth of the above fish and following fishes which belong to *Sebastodes*, are arranged in bands, while those of the present species grow in single irregular rows (toward the end of the jaws, however, they are arranged in bands). The gill-rakers are approximately the same, except that the number is a triflle less, it being 21 to 24.

There are scarcely any melanin chromatophores on the peritoneum of the above species but the peritoneum of the present species is black. There is 1 pyloric appendage less than the previous species, 9 being the usual number. The rest,

Table 33

Stomach contents of *Sebastodes flammeus*

Body length (cm)	43	41	41	40	40	39	38	36
Body weight (g)	1700	1500	1950	1400	1600	1400	1400	1150
Sex				[illegible]				[illegible]
Stomach contents								
Cottidae		1						
Lantern fishes	5	+	6					
Shrimp *Acanthephyra* sp								
Eupausia								
Jaws of cuttle fishes					3			
Cuttle fishes			1					
None				+		+	+	+
Stomach turns out				+		+	+	+

such as the stomach being ┤ shape, the length of the intestine and its type of winding, folds of the mucous membrane, the left lobe being larger than the right, etc are all exactly the same as those of the above species

B Feeding Habits

This fish is generally found in a depth of 200 to 300 meters at muddy bottoms Through the kindness of Mr H Higasi, I was able to make an examination of the stomach contents of those caught off the coast of Tyôsi, Tiba Prefecture

It will be seen from the above analysis (Tab 33) that the usual food of this fish is lantern and luminous fishes, deep sea animals. On account of the size of its air bladder, when it is suddenly fished out, owing to the change of pressure, the air bladder becomes enlarged and presses against the stomach, turning the stomach out into the mouth cavity through the pharynx

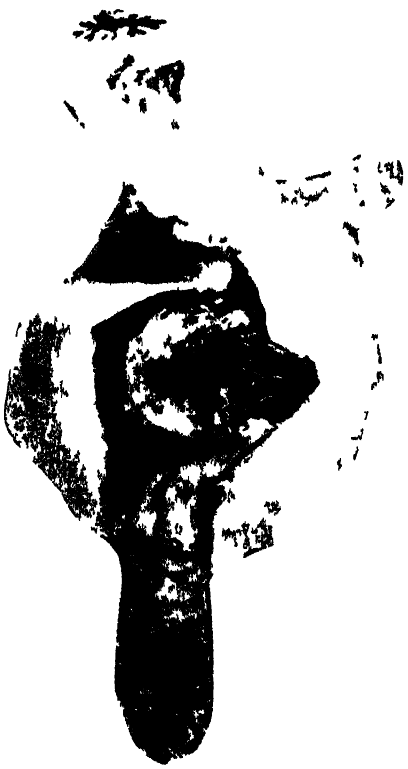


Fig 115 Lantern fishes in the stomach of *Sebastodes flammeus*

109. *Sebastodes matsubarae* (Hilgendorf): Akô.

A. Digestive System.

Teeth in very narrow bands. Gill-rakers 21 to 23 in number. Peritoneum black. Pyloric appendages 9, occasionally 10. There are no other characteristics worth describing (Pl. VII, Fig. 9).

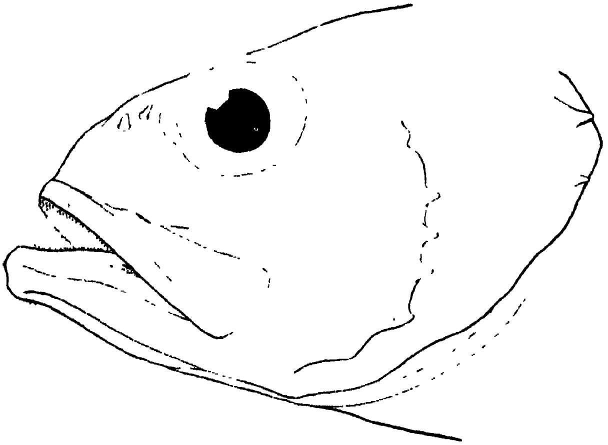


Fig. 146. *Sebastodes matsubarae.*

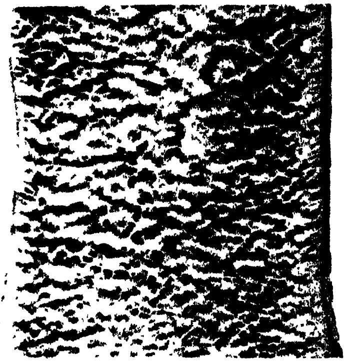


Fig. 147. *Sebastodes matsubarae.* Folds of intestinal mucous membrane.

B. Feeding Habits.

When I made an analysis of the stomach contents of those caught off the coast of Tyôsi, Tiba Prefecture, on May 19th, 1936, I found that they consisted of the jaws of cuttle-fishes and shrimps, such as *Crago* and *Acanthephyra* (Tab. 34).

Table 34

Stomach contents of *Sebastodes matsubarae*

Body length (cm)	64	63	61	69	58	56
Body weight (g)	5200	6400	6800	5800	5100	4400
Stomach contents \ Sex	:	:	♀	:	:	♂
Shrimps··*Crago* sp.,						1
Acanthephyra sp.	1					
Cuttle-fishes			+			+
Stomach turns out		+		+	+	

110. *Sebastodes iracundus* (Jordan et Starks): Ôsaga.

A. Digestive System.

This species is the largest of *Sebastodes*. There is no outstanding difference in its digestive system in comparison with the above species. Peritoneum black; air-bladder large.

B. Feeding Habits.

When I examined 10 of this fish (48 to 63 cm in body length), through the courtesy of Mr. H. Higasi, caught off the coast of Nakaminato, Ibaraki Prefecture, on May 6, 1936 and 20 (45 to 62 cm in body length) of those caught on the 29th of the same month, the 1 sample weighing 5800 grams and 59 cm in body length from the first lot had traces of having eaten some cuttle-fishes, but the stomachs of the other 9 had turned out and no contents could be found. 17 of the latter lot had turned-out stomachs too and no contents could be found; only 3 showed traces of having had some cuttle-fishes.

111. *Sebastodes baramenuke* (Wakiya): Baramenuke.

A. Digestive System.

Nothing to describe in particular. except that the teeth are particularly like those of *S. Matsubarae*.

A report, insofar as the teeth, mouth and gill-rakers of the *Sebastodes* described above are concerned, was written by Wakiya (1917).

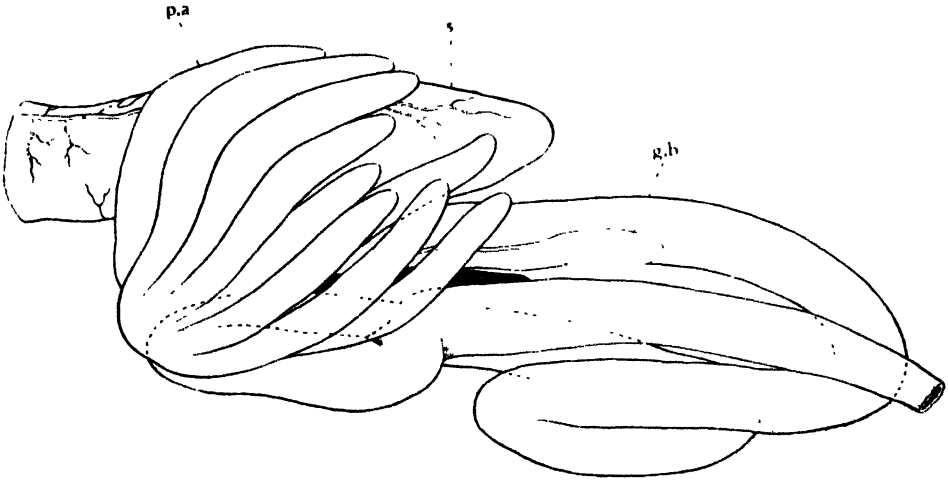


Fig. 148. *Sebastodes baramenuke.*

B. Feeding Habits.

The stomach contents of those (10 fishes, 29 to 38 cm in body length) caught off the coast of Sanriku on May 1 and 13, 1936 which I examined through the courtesy of Mr. H. Higasi consisted mostly of lantern-fishes and *Euphausia* etc. In 1929, when the Muroran Branch of the Hokkaidô Fisheries Experimental Station examined the stomach contents of 34 fishes (26.6 to 39.3 cm in body length) collected near the waters of Muroran, they found that they had eaten small herrings and shrimps, etc., although many of them had empty stomachs.

112. *Sebastiscus marmoratus* (Cuvier et Valenciennes): Kasago.

A. Digestive System.

As the foregoing 5 species all belong to the same Genus *Sebastodes*, their digestive system have a strong resemblance to one another, but the present species, belonging to the Genus *Sebastiscus*, differs somewhat.

The lower jaws of the foregoing 5 species are longer than the upper but those of the present species are of equal length, or even the lower jaw slightly included. The teeth are arranged in rather wide bands, the ends of the premaxillaries being especially wide, and slightly narrower bands are found on the vomer and palatines. Tongue small and trianguloid, not being free is one of its characteristics. Gill-rakers short, tips blunt, on which are small numerous processes, 14 to 15 in number. Pharynx with a muscular wall, the mucous membrane consisting of deeply grooved longitudinal folds, on account of which the power of swallowing food is very strong.

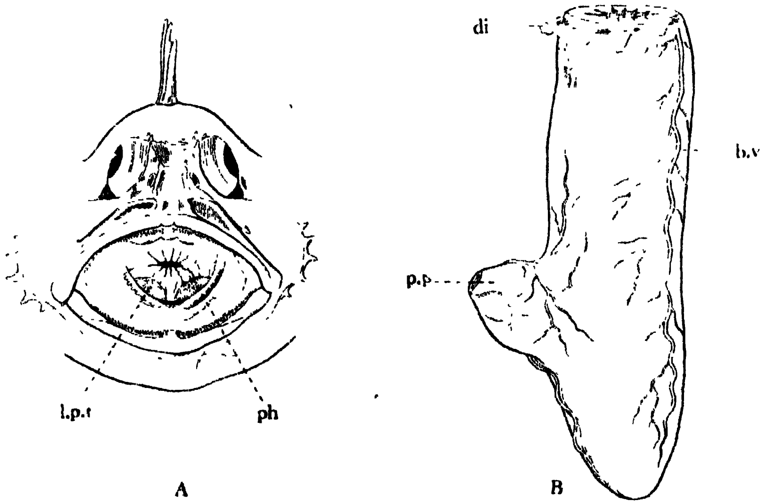


Fig. 149. *Sebastiscus marmoratus*. A. Front view of mouth. B. Stomach.

Peritoneum white. Stomach ┤-shape, the same as the above species. The other digestive tracts do not have anything that requires special mention, only the folds of the intestinal mucous membrane are branch folds instead of net-work (Pl. XII, Fig. 31). Liver also 2 lobes, the left being larger than the right. Air-bladder extremely large, with a thick wall. The fact that the stomach, when fished out of the water, turns out through the pharynx is the same as in the case of the above species.

B. Feeding Habits.

From my examination of the stomach contents of those (15 fishes, about 13 cm in body length) collected at Mito, Sizuoka Prefecture, on August 1, 1931 and those (10 fishes: 15 to 17.7 cm in body length) caught near the Misaki Marine Biological Station on August 10th, 1933 and the 5 fishes (16 to 18.7 cm) collected by Mr. S. Miyauti at Yokosuka on May 3rd, 1937, I am inclined to think that this species feeds chiefly on Crustacea living near rocks in shallow water and prefer such food as Megalopa larvae.

According to Miyauti (1936, p. 5), it would seem that the Japanese scorpion-fishes generally feed at night.

113. *Inimicus japonicus* (Cuvier et Valenciennes) : Oniokoze.

A. Digestive System.

The external and internal appearances of this fish have a very different aspect from those of above-mentioned fishes of Scorpaenidae.

Body elongate, slightly compressed, covered with smooth skin ; head depressed fantastically formed ; body, head and fins with skinny flaps. Mouth small, almost vertical. Band of small conical teeth on each jaw and vomer ; none on palatines. Mouth cavity large ; tongue short, triangular, free anteriorly, soft, no teeth on the surface. Upper and lower pharyngeal teeth developed. Gill-rakers represented by many small bunches of setae (Pl. IV, Fig. 14).

Fig. 150. *Inimicus japonicus.* Dorsal view of head.

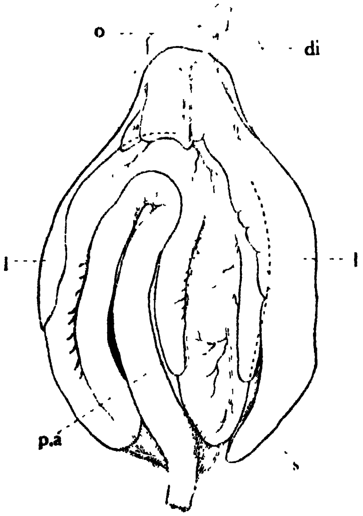


Fig. 151. *Inimicus japonicus.* Ventral side.

Peritoneal cavity moderately large and depressed ; peritoneum pale. Stomach fairly large, ˥-shape, wall thick, mucous membrane with longitudinal folds. Intestine moderately long (the length being ca. 3 2 times d∼a), winds twice horizontally, wall rather thick, mucous membrane assumes net-work folds. Wall of rectum thicker than that of the middle intestine. Pyloric appendages long and broad, 4 in number.

Liver large, 2 lobes, left lobe slightly longer than the right, hanging over the digestive tract. Gall-bladder spherical, moderately large. Digestive organs covered by a membrane. Air-bladder large, wall thick.

B. Feeding Habits.

9 fishes which I collected from adjacent waters of Mituhama, Ehime Pref. on Apr. 25, 1936, had taken the bottom fishes, shrimps and crabs in their stomachs.

Family HEXAGRAMMIDAE

111. *Hexagrammos otakii* (Jordan et Starks) Ainame

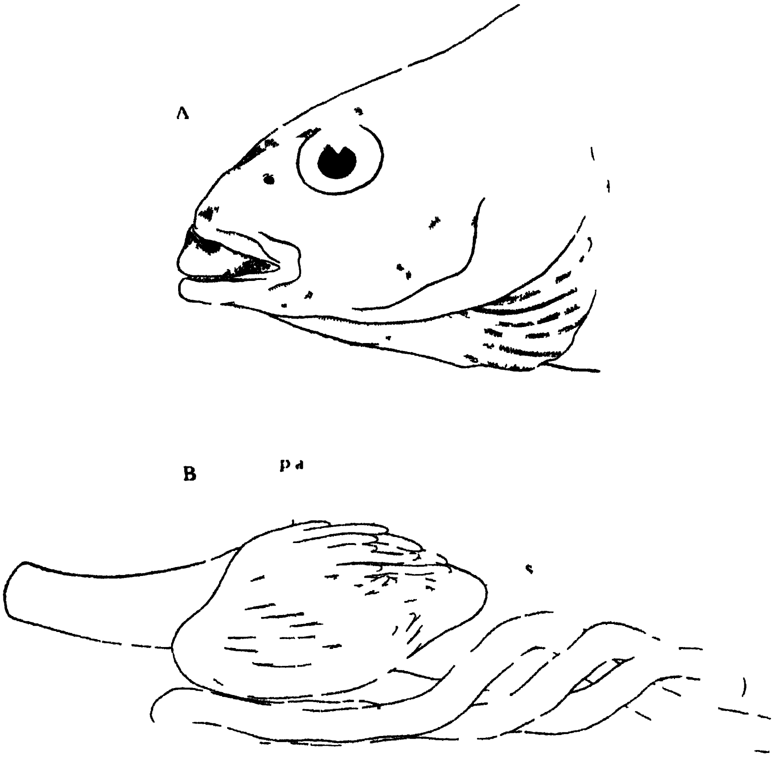


Fig 152 *Hexagrammos otakii* A Head B Digestive tract

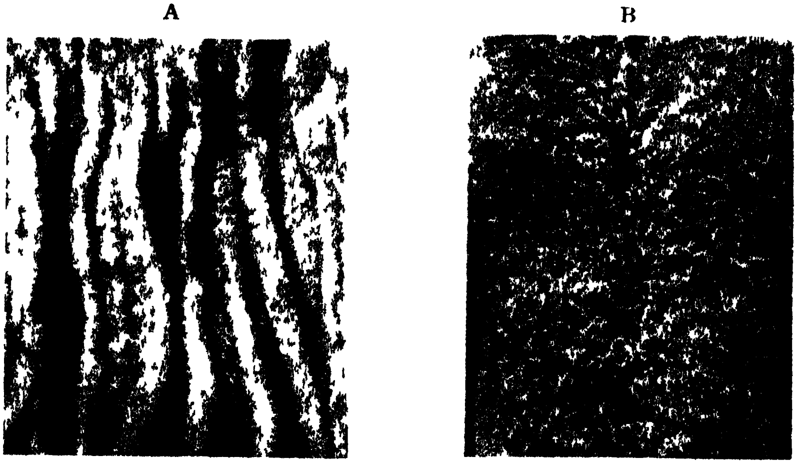


Fig 153 *Hexagrammos otakii* A Folds of mucous membrane of stomach B The same of intestine

A. Digestive System.

Body oblong, more or less compressed. Mouth rather small (m-c being ca. 5/21, m-b ca. 5/31 of head length), horizontal; lips rather thick. Jaws with bands of moderately large, conical teeth, the outer row enlarged. Mouth cavity moderately large: teeth on vomer but none on palatines. Tongue triangular, wide, free, hard, no teeth and melanin chromatophores on the surface. Pharyngeal teeth very minute, closely set. Gill-rakers very short, rather closely set, 16 to 17 in number (Pl. IV, Fig. 5).

Oesophagus wide, wall thick: the folds of mucous membrane longitudinal. Stomach moderately large, Y-shape: blind sac large and pyloric part small; wall of stomach rather thick, mucous membrane consists of about 8 longitudinal folds and net-work folds between those folds. Intestine long, the length being ca. 4.5 times d∼a), makes a characteristic winding, as shown in the figure, there is some resemblance between the intestinal winding type of this species and that of *Engraulis japonicus*, wall rather thin, the folds of mucous membrane double net-work. Pyloric appendages rather long and slender, 45 to 50 in number. Mesentery well developed. In the winter season, fat-cell densely distributed along the mesentery.

Liver 2 lobes, left lobe larger than the right; gall-bladder a long sac, located under the cardiac part of stomach. Spleen large, situated near the

Table 35

Stomach contents of *Hexagrammos otakii*

Date	July 7, 1936	Nov. 21, 1935	Feb. 10, 1932	Frequency
Locality	Ogori Yamaguti Pref.	"	Tokyo Fish Market	
Number of fish	20	7	9	
Ave. body length (cm) Stomach contents	10.2	19.4	20.1	
Gobiidae	1	1		2
Eggs of fishes		2		2
Certain crabs			5	5
Megalopa larvae of crabs	1			1
Inachinae	1			1
Kaikamuri (*Dromia dehaani*)		2		2
Spirontocaris sp.		1		1
Shripms	9	3	2	14
Paguridae	2			2
Eupagurus		1		1
Isopoda	7		1	8
Clam worms		1	1	2
Brown algae	2			2
Calcareous algae		1		1
Stones		2	1	3
None	1		2	3

pyloric appendages.

B. Feeding Habits.

Judging from the results of my observation on the stomach contents of this fish (Tab. 35), it would seem that this fish principally takes the bottom animals for its food.

115. *Agrammus agrammus* (Temminck et Schlegel): Kuzime.

A. Digestive System.

As the digestive system of this fish has a strong resemblance to that of the above species, I shall give only the points that differ, as follows: the jaw teeth do not take as clear a conical form as those of the above species. The gill-rakers are practically the same, except that the number is 2 or 3 less, viz. totalling 13 to 14. Pyloric appendages trifly broader, numbering 20 to 22, being about 1/2 of the foregoing species. Form of stomach, length of the intestine and its type of winding, folds of the mucous membranes of the stomach and intestine are all so alike that it is difficult to distinguish any difference.

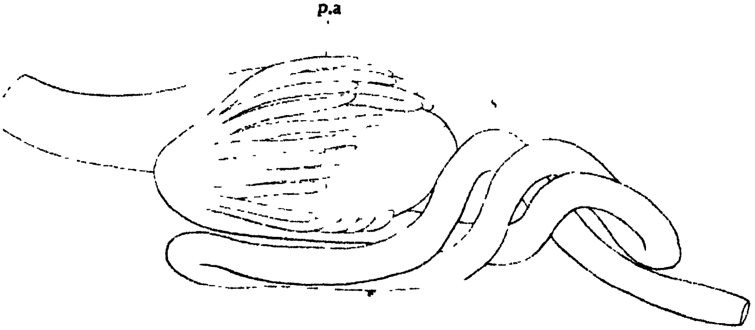


Fig. 154. *Agrammus agrammus*.

B. Feeding Habits.

The 4 samples which I had obtained from the Tokyo Fish Market on Apr. 17, 1936 (ranging from 20.1 to 23.4 cm in body length) had eaten *Ammodytes personatus*, brittle-stars, and other various bottom-living Crustacea.

Family COTTIDAE

116. *Pseudoblennius percoides* (Günther): Anahaze.

A. Digestive System.

Body rather elongate, compressed posteriorly; head rather pointed. Mouth wide (m-c being ca. 2/5, m-b ca. 3/7 of head length); upper jaw longer than the lower. Teeth in jaws conical and slender, directed inward, arranged in rows. Vomer and palatines armed with small conical teeth; tongue small, triangular, thick, free, no melanin chromatophores and teeth on the surface (Pl. III, Fig. 2). Pharyngeal teeth almost the same size with jaw teeth. About 10 bunches of setae grown on a gill-arch in place of the gill-rakers.

Peritoneal cavity moderately large; peritoneum silvery. Stomach large, V-shape, blind sac large oval, and pyloric part small. Wall of stomach tolerably thick, the mucous membrane consists of about 10 longitudinal serpentine folds. Intestine short (the length being ca. 2.2 times d~a), winds twice, narrow, wall thin, mucous membrane consists of net-work folds. Pyloric appendages long (the longest one being as long as 2/3 of the length of stomach), ca. 10 in number.

Liver large, 2 lobes, located on the left and ventral sides of stomach; gall-bladder small, located underneath of the pyloric appendages.

B. Feeding Habits.

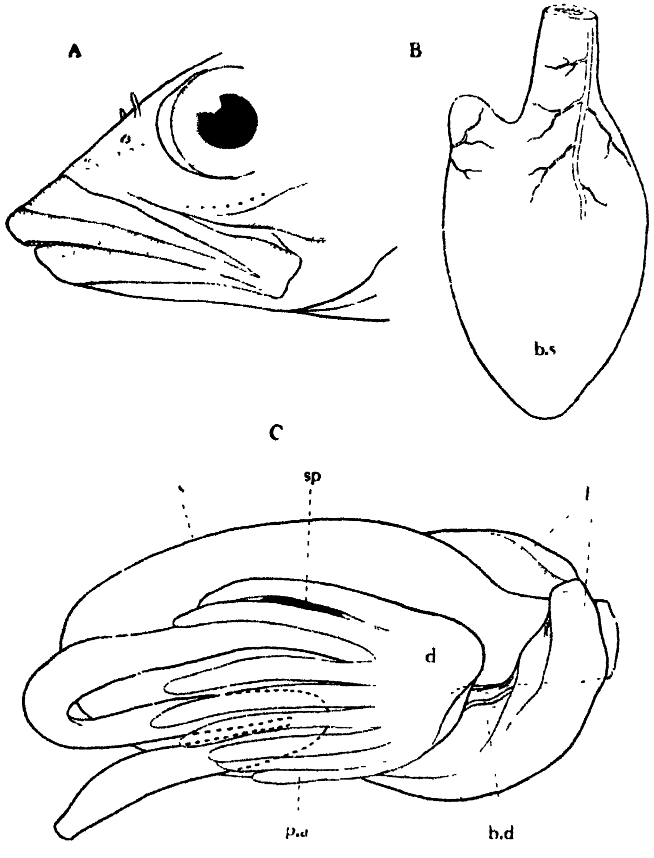


Fig. 155. *Pseudoblennius percoides.* A. Head. B. Stomach. C. Digestive tract.

This fish is usually found near the rocky places along the entire coast line of middle Japan. It is sluggish but voracious, it feeds mainly on Amphipoda, Paguridae, dead fishes, mingled with sand particles.

117. ***Pseudoblennius cottoides*** (Richardson) : Asahinahaze.

Digestive system of this fish is almost the same as that of the above-mentioned species.

118. *Pseudoblennius marmoratus* (Döderlein): Ayaanahaze.

There is hardly any difference between the digestive system of the present species and the above-mentioned species saving the slight difference of the size of teeth.

Family PLATYCEPHALIDAE

119. *Platycephalus indicus* (Linné): Koti.

A. Digestive System.

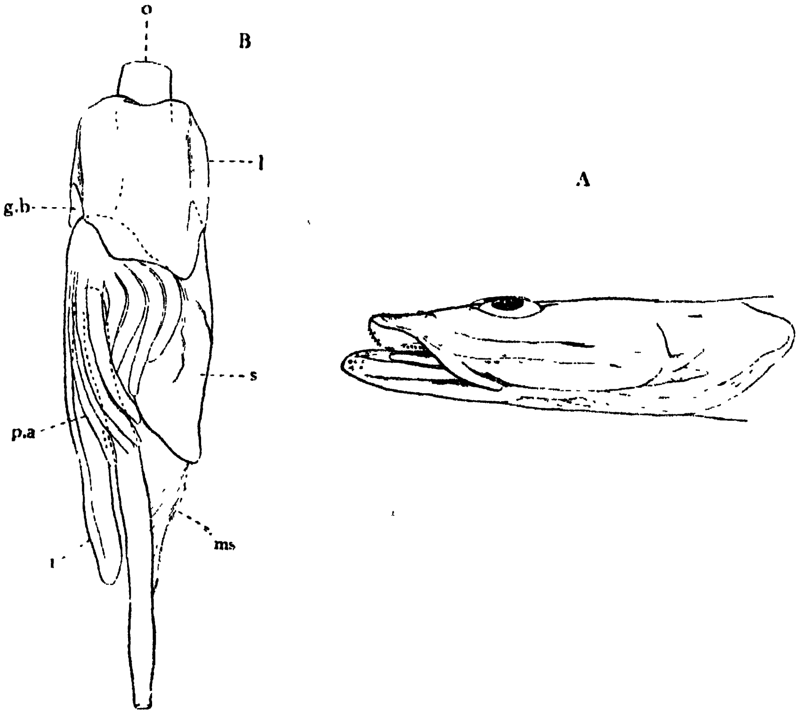


Fig. 156. *Platycephalus indicus.* Ventral side. A. Head. B. Digestive tract.

Body depressed anteriorly, sub-cylindrical posteriorly. Head depressed and smooth. Mouth large, especially the breadth wide (m-c being ca. 1/3 and m-b ca. 2/3 of head length); lower jaw slightly longer than the upper; lips thin; jaw teeth villiform, a band of which in both the upper and lower jaws. Mouth cavity depressed; vomer with small canine-like teeth in a crescent band and palatines with a single row of most prominent canine-like teeth. Tongue very thin, moderately large, square in shape (which is very rare), free anteriorly, surface smooth, dented somewhat, no melanin chromatophores (Pl. III, Fig. 13). Pharyngeal teeth about twice as large as the jaw teeth and those on the upper pharyngeal bone are larger than those on the lower. Gill-rakers flat, only 4 to 6 at the curve of the gill-arch, the others being rudimentary, and the longest of them is a littltle shorter than the corresponding gill-filaments.

Peritoneal cavity rather small and slightly depressed; peritoneum silvery and some melanin chromatophores. Oesophagus wide, with a thick wall. Stomach ┤-shape but akin to Y-shape; blind sac large and elongate; wall of stomach thick; mucous membrane of the cardiac part consists of about 10 longitudinal serpentine folds, and that of the blind sac net-work; pyloric part short, with a rather thin wall. Intestine stretches along the right side of the stomach and winds twice, wall of which rather thick and the mucous membrane consists of longitudinal folds and warts between the folds. Middle intestine and rectum are not distinct internally but the former is a little wider than the latter. Pyloric appendages 6, rarely 7, all long.

Liver small and thick, consists of 2 lobes, the left lobe being larger than the right; gall-bladder ellipsoid, located at the terminal of the right lobe of the liver; cystic duct long.

Okamoto (1918) reported that the pyloric appendages of this fish numbered 11 but I am inclined to think that there was a misjudgement in the species, and that it was not a real Koti he examined.

B. Feeding Habits.

As may be seen from the table below, this species seems to be a real bottom feeder.

Table 36

Stomach contents of *Platycephalus indicus*

Date	May 13, 1938	Apr. 1, 1937	Frequency
Locality	Tokyo Fish Market	Kannonzi, Kagawa Pref.	
Number of fish	12	14	
Av. body length (cm) / Stomach contents	—	32.1	
Kurakakegisu (*Neopercis sexfasciata*)	3		3
Certain crabs	1	7	8
Kobusigani (*Leucocides obtusifrons*)		4	4
Clam-worms	2	2	4
Ophiuroidea	8	5	13

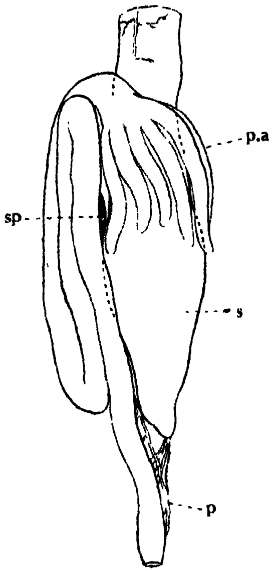


Fig. 157. *Inegocia japonica.* Ventral side.

120. *Inegocia japonica* (Tilesius): Tokagegoti.

The digestive system of this fish is almost the same as the above species, and there is hardly any difference in the form of the stomach, the length of the intestine and its type of winding, the folds of the mucous membrane, and the number of the pyloric appendages, etc. However, the teeth on the vomer and palatines are trifly smaller.

Family AGONIDAE

121. *Podothecus acipenserinus* (Tilesius).

A. Digestive System.

Body elongate, angular. Head irregularly triangular as viewed from above. Mouth wide, entirely inferior, crescent as viewed from below. Jaw teeth few and weak, excessively so in the upper jaw. Patches of barbels in the front and back of the mouth. Mouth cavity small; no teeth on vomer and palatines; tongue rather large and thick, semi-elliptic, free anteriorly, no melanin chromatiphores on the surface but longitudinal folds instead. Pharyngeal teeth villiform. Gill-rakers very short and coarse, merely triangular processes, 13 in number.

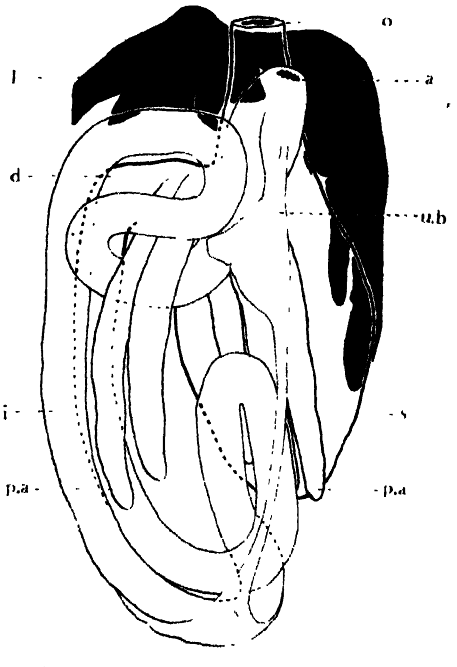


Fig. 158. *Podothecus acipenserinus.* Ventral side.

Peritoneal cavity rather large; peritoneum silvery, on the surface of which scatter melanin chromatophores. Stomach rather large, V-shape, wall thick, mucous membrane fine longitudinal folds which run into each other at some places. Intestine rather long and moderately wide, wall rather thick, mucous membrane consisting of folds of indistinct polygonal network, which looks almost smooth to the naked eye. Anus opens just in front of the anal fin. As the anal fin is located very near the mouth, the anus also opens in its neighborhood. Pyloric appendages 6 to 7.

Liver rather large, poly-lobes, lobes on the left side being rather long. On the ventral side of the digestive tract is the urinary-bladder, ureter opening at the end of the rectum.

B. Feeding Habits.

According to Gilbert, this is one of the most abundant species in Alaska and may be found anywhere in the shallow waters in the vicinity of the Aleutian Islands. It is a bottom fish, and the 5 samples (21.0 cm 24.3 cm in body length, ♀ : ♂ =3 : 2, caught near the Aleutian Islands on June 30, 1930) which I obtained had eaten *Crago septemspinosus*, Diastylidae (Cumacea), Amphipoda, sand particles, and diatoms, despite the fact that the gonads of females were mature. It would seem that this fish takes bottom creatures for its daily food, and the fact that its mouth is located entirely on the ventral side of the body gives the impression that it must be very convenient to have the mouth located where it is to take bottom food.

Family Triglidae

122. *Lepidotrigla micropterus* (Günther): Kanagasira.

A. Digestive System.

Body elongate, more or less fusiform. Mouth large, inferior, Λ-shape. Teeth very small, in broad bands in jaws and vomer; no teeth on palatines. Mouth cavity medium in size; the folds of palatal mucous membrane logitudinal; tongue moderately large, semi-elliptic, thick, covered by a membrane, barely free anteriorly, no teeth and melanin chromatophores on the surface. Villiform teeth on 3 sets of the upper pharyngeal bones and 1 set of the lower. Gill-rakers short (slightly shorter than corresponding gill-filaments), flat, tips blunt, coarsely grown, 10 to 11 in number, process on each gill-raker numerous.

Peritoneal cavity rather small; very few melanin chromatophores on peritoneum. Stomach moderately large, V-shape; cardiac part as long as blind sac and pyloric part longer than those 2 parts; mucous membranes of cardiac part and blind sac consist of 9 longitudinal serpentine folds and small papillae between those folds (Pl. VII, Fig. 16); folds of pyloric part indistinct. Intestine rather short (the length being ca. thrice d∼a) and broad, winds twice, drawing the letter N; wall thick, mucous membrane consists of network folds. Pyloric appendages wide and long, 8 in number.

Liver rather thick, 2 lobes, left lobe large and long, while the right short and small; gall-bladder medium in size, long ellipsoid. Spleen small, located near the pyloric part of stomach. Air-bladder large, bag-shape, wall thick.

Regarding the digestive tract of *Trigla*, fairly detailed reports have been written by Cuvier and Valenciennes (1833), and Jacobshagen (1911) on *T. hirundo*. According to these reports, the stomach takes the form of the letter V, and the wall is thick. The wall of the intestine, however, is thin. There is no material difference in these descriptions in comparison with the species that I examined, and it is interesting to note that they also give the number of the pyloric appendages as 8. But according to Home (1814), the pyloric appendages of *T. gurnardus* count 6. There is a detailed report by

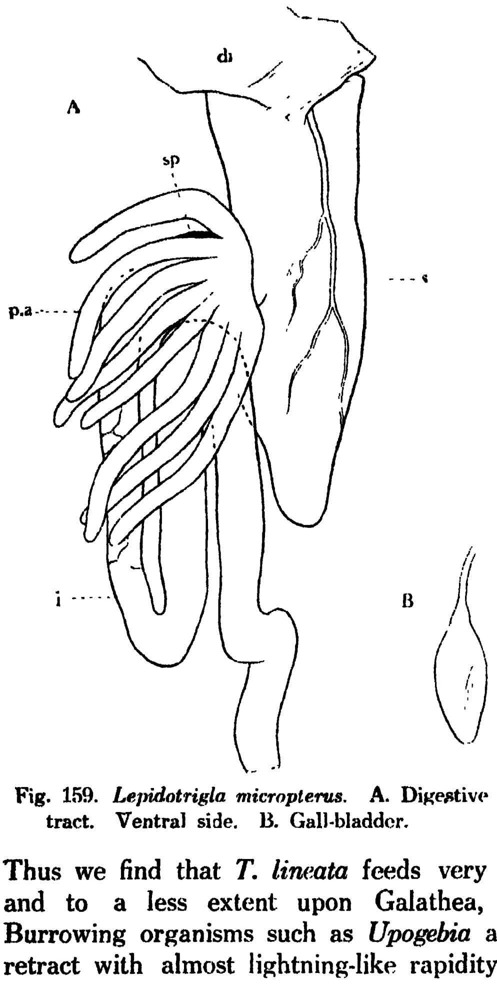


Fig. 159. *Lepidotrigla micropterus.* A. Digestive tract. Ventral side. B. Gall-bladder.

Okamoto (1918) on just the stomach of *Lepidotrigla micropterus.*

B. Feeding Habits.

Instead of taking up any space with my humble report, I shall quote from the very interesting report written by Steven (1930) on the feeding habits of gurnards. According to his various observation of the natural food of those near Plymouth, England, and those cultured in aquarium; "---, of the different gurnards (*Trigla lineata, T. cuculus, T. gurnardus, T. hirundo*), *T. lineata* in the aquarium spends most of its time, crawling over the bottom of the tank by means of its long finger-like pectoral filaments. In addition to their locomotor function, the filaments are also very efficient tactile organs used in the finding and identification of food. .... *T. cuculus. T. gurnardus* and *T hirundo* also possess pectoral filaments and use them in the manner described, but to a progressively less extent. .... Thus we find that *T. lineata* feeds very largely upon *Porcellana longicornis*, and to a less extent upon Galathea, *Portunus pusillus* and Amphipoda. Burrowing organisms such as *Upogebia* and those tubicolus Polychaetes, which retract with almost lightning-like rapidity on the slightest provocation do not figure in its diet any more than do such active swimmers as the Pandalidae, Crangonidae, Palaemonidae, or Pisces."

Family GOBIIDAE

123. *Pterogobius elapoides elapoides* (Günther): Kinubari.

A. Digestive system.

Body cylindrical, compressed posteriorly. Mouth medium in size (m-c being ca. 4/13, m-b ca. 3/7 of head length), directed obliquely upwards; jaws equal; lips thin. Jaw teeth in 2 rows, slender and conical, the inner ones minute, in a narrow band; outer ones much stronger. Mouth cavity moderately large; no teeth on vomer and platines. Tongue medium in size, rectangular, thin, free, no teeth and melanin chromatophores on the surface; Mm. hypobranchiales developed. Villiform teeth on 2 sets of the upper pharyngeal bones and 1 set of the lower pharyngeal bone. Gill-rakers moderately long (the length being ca. 1/2 of corresponding gill-filaments), very slender, coarsely grown, 16 to 18 in number.

Peritoneal cavity small; peritoneum silvery. Oesophagus moderately long, broad, wall thick, mucous membrane with 20 longitudinal folds; Stomach merely a cylindrical tube, short, wall thick, the folds of mucous membrane longitudinal. Intestine short (the length being ca. 1.3 times d~a), winds twice, wall thick, mucous membrane consists of papillary processes which arranged in longitudinal rows. A valve located between the stomach and the intestine. Rectum slightly broader than intestine. No pyloric appendage.

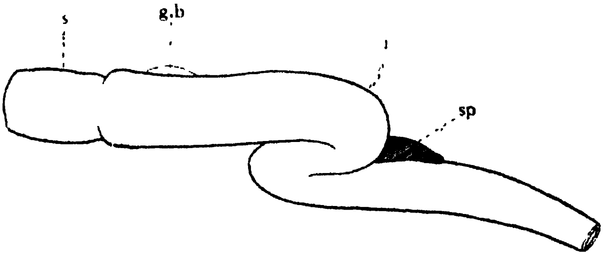


Fig. 160. *Pterogobius elapoides elapoides.*

Liver large and thick, boat-shape, lifting the digestive tract from below; gall-bladder moderately large, ellipsoid; bile and cystic ducts short. Spleen small, located near the boundary between the middle intestine and the rectum. Air-bladder large.

B. Feeding Habits.

The fishes which I collected from the adjacent waters of the Misaki Marine Biological Station, on July 10, 1937 had taken mainly the zooplankton in their stomachs.

121. *Chasmichthys dolichognathus gulosus* (Guichenot): Dorome.

A. Digestive System.

Body oblong, rather robust, compressed posteriorly. Head large, broad, depressed. Mouth wide (m-b being ca. 1/5 of head length); upper jaw slightly longer than the lower. Minute conical teeth in narrow band in each jaw. Mouth cavity very large; no teeth on vomer and palatines; tongue large, triangular, thin, free anteriorly, no teeth, a few melanin chromatophores on the surface. Villiform teeth on 3 sets of the upper pharyngeal bones and 1 set of the lower pharygeal bone. Gill-rakers very short, flat, tips pointed, coarsely grown, 15 to 16 in number.

Peritoneal cavity rather small. Oesophagus short but wide, wall thick, mucous membrane with 17 longitudinal folds. Stomach merely a cylindrical tube, broad, longer than the above species, wall thick, mucous membrane consists of longitudinal serpentine folds. Intestine short (the length being ca. 2.2 times d~a), winds twice, wall thick, mucous membrane with papillary processes. A characteristic valve located between the stomach and intestine. Rectum slightly broader than intestine. No pyloric appendage.

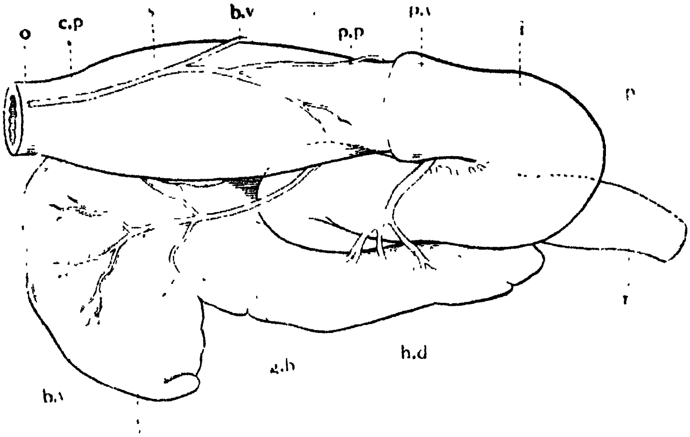


Fig. 161. *Chasmichthys dolichognathus gulosus.*

Liver large, 2 lobes (incomplete boat-shape), right lobe far longer than the left; gall-bladder moderately large, ellipsoid. Pancreas distributed around the intestine. Air-bladder large.

B. Feeding Habits.

During the summer of 1932 and the spring of 1933, I collected 84 samples of this fish, ranging from 7 mm to 100 mm in body length, near Enosima and the Misaki Marine Biological Station and studied the development of their digestive system and the vicissitude of their feeding habits.

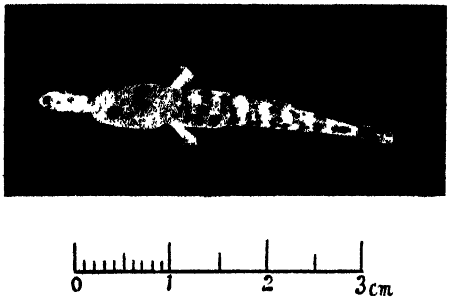


Fig. 162. Eating its own young.

As shown in the Table 37, young fishes from 7 to 10 mm in body length have no teeth, their gill-rakers are in the early stage of development, and their digestive tract is straight. No stomach contents were found, but I am inclined to think that fishes of this size feed on micro-plankton and its kind. They are found under floating algae in their infancy. But when they begin to cut teeth and when the stomach and intestine become distinguishable and the latter begins to wind, that is, when they become 11 to 15 mm in body length, they leave their former habitat, the floating algae, and make school in the upper layer of the sea (generally tide-pools) and feed mainly on copepods. And when they are 15 mm, the teeth are fully grown and the winding of their intestine takes the form of an adult. When they outgrow this size, the feeding habits peculiar to this species set in, that is, they eat each other. When they become over 40 mm, they live near the bottom (genarally the bottom of tide-pools) and feed mostly on the sea-slaters (*Ligia exotica*), Amphipoda, *Nereis*, and their kind, keeping up, at the same time, their internecine struggle.

Table 37

Stomach contents of *Chasmichthys dolichognathus gulosus*

Body length (mm)	Number of fish	Teeth	Gill-raker	Digestive tract	Stomach contents	Habitat
7~10	10		Early stage of growth; short; 12 to 13 in number	Straight from oesophagus to anus; stomach and intestine just barely distinguishable. Liver small.	Indistinct	Under floating algae
11~15	10	Early stage of growth	,,	Intestine develops, making some turns. Intestine and stomach become distinct	Nauplius larvae *Setella* sp. *Idomena* sp.	Gradually schools the upper layer of water
16~20	10	Gradually develops	Gradually develops	Turnings of intestine make further development and becomes fully-growth size	Copepoda Isopoda	Schools the upper layer
21~25	10	Fully growth	,,	Becomes adult form	Copepoda Own young	,,
26~30	10		Fully growth		Own young Small Gastropoda	Gradually leaves the shoal
31~40	5				,,	Gradually sinks to the bottom
41~50	9				Own young *Ligia exotica*	Bottom
51~75	10				*Ligia exotica* Amphipoda *Monostroma* sp. Own young	,,
76~100	10				*Ligia exotica* *Nereis* Own young	

125. *Chasmichthys dolichognathus dolichognathus* (Hilgendorf) : Agohaze.

A. Digestive System.

Only the number of scales and the spots on its body are different to those of the above species, the digestive system being exactly the same.

B. Feeding Habits.

Generally this fish lives in the same tide-pool as that above described, and there is no difference in their feeding habits.

126. ***Boleophthalmus pectinirostris*** (Gmelin) : Mutugorô.

A. Digestive System.

Body elongate, not so much compressed. Head round. Mouth large (m-c being ca. 2/7 and m-b ca. 1/2 of head length) ; upper jaw slightly longer than the lower ; upper lip thick, the lower thin. Jaw teeth incisor-like and small, closely set in a row in both the upper and lower jaws, the front upper jaw teeth consisting of 3 sets of large teeth and the lower 1 set. Mouth cavity rather large ; no teeth on vomer and palatines ; tongue large, semi-elliptic, soft, black, smooth, not free. No pharyngeal teeth. Gill-rakers soft, tips pointed, thin, rather short (the length being 1/5 to 1/6 of corresponding gill-filaments), coarse, approximately 22 in number (Pl. IV, Fig. 16).

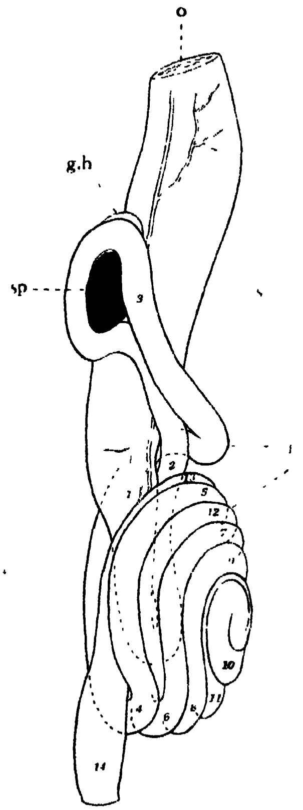


Fig. 163. *Boleophthalmus pectinirostris*. Dorsal side.

Peritoneal cavity medium in size; peritoneum black. Wall of oesophagus thick, lined with longitudinal folds, similar to those of Clupeidae, 18 in number; the boundary between the stomach and the oesophagus being distinct. Stomach, rather long, cylindrical, being thicker than the intestine succeeding it, although distinction may be made between the stomach and the intestine outwardly, there is a valve inside dividing the 2 organs distinctly. Wall of stomach thin, mucous membrane consisting of 15 longitudinal serpentine folds. Intestine extremely long, owing to the herbivorous habits of this fish (the length being ca. 6 times o∼a): as may be seen from the figure, the winding is very peculiar, namely the middle part of the intestine winds clockwise and counter-clockwise just above the right side of the rectum; wall thin; mucous membrane being net-work constituting zigzag folds. No pyloric appendage.

Liver taking form of a boat, big, located below the stomach; gall-bladder spherical and rather large.

B. Feeding Habits.

Prof. I. Amemiya turned over to me of this fish which he had obtained from the Ariake Sea in June 1929 and ordered me to make an examination of their stomach contents. I obtained the results shown in the Table 38, the contents being entirely diatoms. In 1937, through the courtesy of Mr. K. Isoda which he had collected from the Ariake Sea on the 15th Oct. of the same year. The analysis of their stomach contents also showed diatoms only. I believe that it can be safely said that fish specializes in diatoms which thrives on the muddy bottom of shallow water.

Table 38

Stomach contents of *Boleophthalmus pectinirostris*

Date	Locality	Number of fish	Av. body length (cm)	Stomach contents
June, 1929	Ariake Sea	2	—	Diatoms (*Navicula*, *Chaetoceras*, *Coscinodiscus*, *Thalassiothrix*, *Dactyliosolen* etc.)
Oct. 15, 1937	,,	30	7.1	Diatoms (*Pleurosigma*, *Nitzschia*, *Chaetoceras*, *Amphora*, *Coscinodiscus*, *Biddulphia*, etc.)

127. *Periophthalmus cantonensis* (Osbeck): Tobihaze.

A. Digestive System.

Body elongate, rather compressed. Mouth large (m-c being ca. 5/17, m-b ca 5/8 of head length); upper jaw slightly longer than the lower; jaw teeth small; a row of about 20 teeth in each jaw. Mouth cavity depressed, rather large; no teeth on vomer and palatines; tongue large, triangular, not free, covered with a rather thick membrane. Pharyngeal teeth so small that, if felt, they may be felt on the finger. Gill-rakers very short, merely small triangular processes, 16 to 18 in number.

Peritoneal cavity moderately large; peritoneum black. Stomach a rather short and straight cylinder. may not be distinctly distinguished from the intestine outwardly but the mucous membrane within. Mucous membrane of the former consists of approximately 12 longitudinal folds and the latter folds similar to the veins of a leaf. Intestine rather long (the length being ca. 2.5 times o∼a), wall thin, winds 4 times. It is worth nothing that owing to the liver being situated on the ventral side, the intestine is located on the dorsal side of the stomach. No pyloric appendage.

Liver large and long, consisting of 2 lobes, located at the ventral side of the digestive tract; gall-bladder large, spherical. Spleen small.

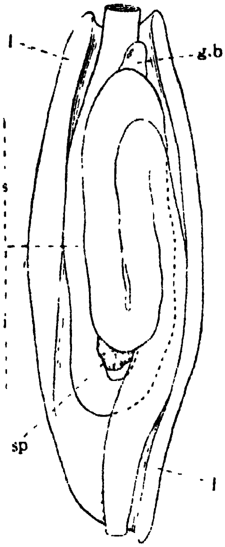


Fig. 164. *Periophthalmus cantonensis.* Dorsal side.

B. Feeding Habits.

Periophthalmus has the very curious habits of coming out of the water, jumping about on the shore, and even climbing trees. Owing to its peculiarities, as already stated, the habits of this fish have drawn the attention of many people. According to Hickson (1889), it not only feeds on animals in the water but on crabs crawling along the shore and insects flying in the air. As for the feeding habits of Japanese *Periophthalmus*, the species under review, Uchida (1935) says that it eats small animals along the beach, such as little crabs and worms, etc.

128. *Trypauchen vagina microcephalus* (Bleeker): Akauwo.

A. Digestive System.

Body very long, greatly compressed. Eyes very small. Mouth moderate (m-c being ca. 2/7, m-b ca. 2/5 of head length), directed obliquely upwards; lower jaw longer than the upper; lips rather thick. Teeth in 2 rows, the outer ones enlarged; no canines. No teeth on vomer and palatines. Tongue large, oval, thick, free anteriorly, no teeth and melanin chromatophores on the surface. Upper pharyngeal teeth rather developed. Gill-raker rudimentary.

Peritoneal cavity exceedingly small; no melanin chromatophores on peritoneum. Oesophagus rather short and wide, wall thick, mucous membrane consists of 18 longitudinal folds. Stomach merely a cylindrical tube, bulgy in

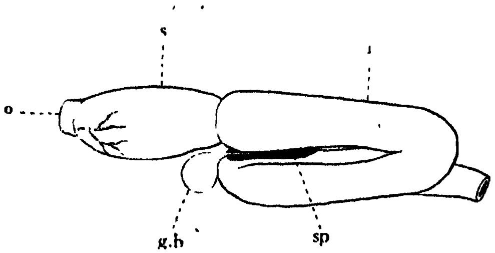


Fig. 165. *Trypauchen vagina microcephalus.*

the middle; wall thick, mucous membrane consists of 8 longitudinal folds. Stomach and intestine clearly distinguished externally by a constriction and internally by a valve. Intestine short (the length being ca. thrice d∼a), winds twice forming a letter N, wall rather thick, mucous membrane with papillary processes. Anus opens just in front of the anal fin. Mesentery densely distributed.

Liver large, thick, boat-shape, lifting the entire digestive tract from below; gall-bladder moderately large, spherical. No pyloric appendage. Spleen located near duodenum.

B. Feeding Habits.

According to my examination of the stomach contents of 12 fishes (9.8 cm in average body length) collected from the adjacent waters of Tomo, Hirosima Prefecture on Mar. 26, 1936, I found that every one of them had taken the moderate quantity of small dead animals (?) and other various dirty stuff, as well as the mud at the bottom of the sea.

Family ECHENEIDAE

129. *Echeneis brachyptera* (Lowe): Kurokoban.

A. Digestive System.

Body rather robust, compressed behind; a elliptic sucker on the dorsal side. Mouth large (m-c being ca. 1/2 of head length, m-b being broader than m-c), oblique, lower jaw much projected. Small and sharp teeth on the jaws, vomer, palatines and tongue; those of the inner series in the upper jaw and outer series in the lower, larger than others. Buccal cavity depressed, tongue small, semi-elliptic, free, armed with teeth. Pharyngeal teeth small, the upper divided into 3 sets. Gill-rakers grow coarsely, slender and short (the length being ca. 1/3 of corresponding gill-filaments), vertical to the gill-arch, flat, numbering 13.

Peritoneal cavity moderate in size; melanin chromatophores none whatever on the peritoneum. Digestive tract a wide, straight tube; 1/3 of the front part of which being the stomach and the latter 2/3 the intestine; at the end of the intestine is the rectum; the stomach, intestine and rectum being distinctly divided by valves; walls of the stomach, intestine and rectum thick alike; mucous membrane of stomach consists of about 10 longitudinal folds, that of the intestine consits of long papillary processes (Pl. XI, Fig. 23), and that of the rectum short papillary processes. Like those of the tunny, the pyloric appendages of this fish are a mass of small clusters covered with a piece of membrane which looks something like the liver, and covers the lower left of stomach. Gall-bladder spherical and rather large; Ductus choledochus

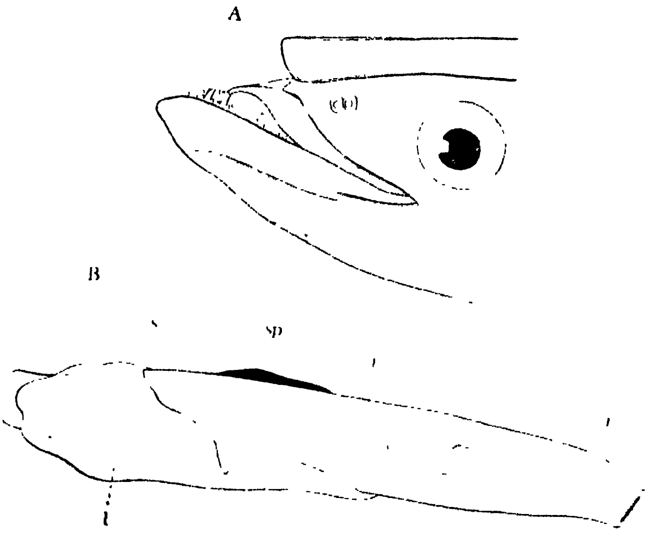


Fig. 166. *Echeneis brachyptera.* A. Head. B. Digestive tract.

short and opens at the beginning of intestine. Liver small, consisting of 1 lobe and situated at the lower part of the cardiac part. No air-bladder.

Jacobshagen (1911) examined the digestive tract of *Echeneis remora* and pointed out that it consists of a V-form stomach and an intestine that makes short turnings. It is uncommon that fishes which belong to the same genus *Echenis* should have such different digestive tract.

B. Feeding Habits.

As the fishes which belong to the family Echeneidae stick themselves fast to the large fishes with their suckers, it has often been discussed among the fishermen as to their method of obtaining food. According to the late Mr. Kumakiti Aoki of the Misaki Marine Biological Station, the fishes feed on the food which the larger fishes, such as sharks and swordfishes, drop while they themselves are feeding. But S. Nakamura (1935), who observed the feeding habits of the *Leptecheneis naucrates* which had attached itself to a shark, in the aquarium at Kominato, Tiba Prefecture, wrote in his report that the fish detached itself from the shark in order to get its food, but as soon as it saw that the shark was swimming away, it would immediately give up its food and go back to the shark. Jordan (1907), in p. 679, and Boulenger (1922), in p. 691 of their books respectively, state that the fishes of the family Echenidae are carnivorous. In June 1935, I examined the stomachs of 3 fishes (body lengths 5.7, 5.9, 6.2 cm) which were attached to *Makaira mitsukurii* caught off Izu Peninsula and found them entirely empty.

Family URANOSCOPIDAE

130. *Uranoscopus japonicus* (Houttuyn): Misimaokoze.

A. Digestive System.

Body rather elongate, not compressed. Head large. Mouth large (m-c being ca. 1/3, m-b ca. 2/3 of head length), directed almost vertically upwards; lower jaw situates in front of the upper; lips thin, fringed with papillae. Teeth in jaws small and conical, arranged in 3 to 4 rows in upper jaw, and in 1 or 2 rows in the lower. Mouth cavity rather small; vomer and palatines with a narrow patch of teeth. Tongue large, semi-circular, free, no teeth and melanin chromatophores on the surface. Pharyngeal teeth villiform. Gill-rakers obsolete, represented by 17 small bunches of setae (Pl. IV, Fig. 13).

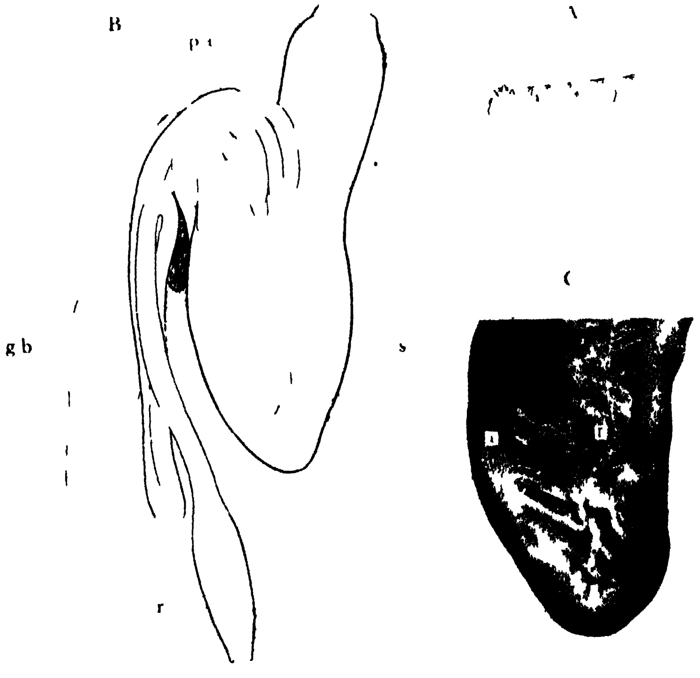


Fig. 167. *Uranoscopus japonicus*. A. Gill-rakers. B. Digestive tract. Ventral side. C. Pancreas on mesentery.

Peritoneal cavity moderately large, no melanin chromatophores on peritoneum. Oesophagus long with thick wall, mucous membrane consists of 14 longitudinal folds. Stomach rather large, V-shape, blind sac the largest. Wall of stomach thick, the mucous membrane having longitudinal serpentine folds. Intestine moderately long (the length being ca. 2.8 times d~a), winds twice, wall rather thick, mucous membrane consists of longitudinal tortulous folds. Last 1/8 of intestine being the rectum; rectum wider than the middle intestine, and the two parts clearly distinguished by a valve. Pyloric appendages 8, rather wide but short.

Liver 2 lobes, left lobe ca. thrice as long as the right, thin, covering the digestive tract from above; gall-bladder extremely large, ellipsoid. No air-bladder.

B. Feeding Habits.

I did not have a chance to study the feeding habits of this fish, and so I shall give the purport of an article which appeared in the Ann. and Mag. Nat. Hist., 1890, II, p. 205. Of 25 *Uranoscopus crassiceps* caught in the bay of Bengal, in a depth of 98 to 102 fathoms, the investigator found that one of them had eaten 7 *Scopelus pterotus* (from the book written by Goode and Bean, 1895, p. 294).

Family AMMODYTIDAE

131. *Ammodytes personatus* (Girard): Ikanago.

A. Digestive System.

Body elongate, lanceolate. Snout pointed; mouth moderately large (m-c being ca. 1/3, m-b ca. 1/6 of head length), directed obliquely upwards; lower jaw longer than the upper; lips thin. Jaws without teeth. Tongue medium in size, elongated trianguloid, thin, free, melanin chromatophores on the surface. Villiform teeth on pharyngeal bones. Gill-rakers long (as long as corresponding gill-filaments), flat, tips rather pointed, closely set. 18 to 22 in number.

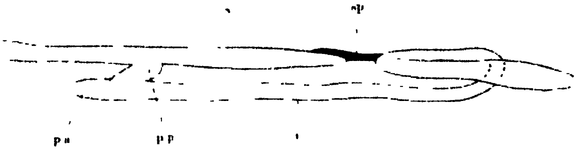


Fig. 168. *Ammodytes personatus.*

Peritoneal cavity elongate; peritoneum with melanin chromatophores. Oesophagus wide, wall thick, 14 longitudinal folds on the mucous membrane. Stomach elongate, ⅂-shape, wall rather thick, mucous membrane consists of 12 longitudinal folds; pyloric part with the thickest wall, folds of mucous membrane 7 to 8 rows in this part. Intestine short (the length being ca. 1.4 times d~a), having 2 short turnings, rather narrow and thin, mucous membrane with longitudinal serpentine folds of small papillary processes. Pay your attention to the characteristic mode of connection between the pyloric part of stomach and duodenum. Rectum broader than the middle intestine. No pyloric appendage.

Liver 2 lobes, left lobe as long as the right, rather thick, lifting the stomach from below. Gall-bladder spherical; bile duct rather long. Spleen small, located near the blind sac of stomach.

Rathke (1824) describes that the *Ammodytes tobianus* has the pyloric appendages.

B. Feeding Habits.

According to Bigelow and Welsh (1925, p. 185), the sand-eels (*Ammodytes americanus*) are omnivorous, feeding on all sorts of small marine animals, but chiefly on small Crustacea, especially copepods, and on fish fry, including their own kind. In Scandinavian waters, indeed, the larger ones seem to live chiefly on the smaller. Worms have also been found commonly in the stomachs of sand-eels, but it is not likely that they catch these while burrowing, as some writers have suggested.

Family BLENNIIDAE

132. *Salarias enosimae* (Jordan et Snyder): Kaeruuwo.

A. Digestive System.

Body deep and greatly compressed. Mouth small. A row of minute teeth in both jaws; gill-rakers short. According to Ishida (1935), the oesophagus and stomach are both thick and short; the intestine, narrow and extremely long, winds several times. (He was the one who discovered that ciliated epithelium composed the central part of the intestine). Cuvier and Valenciennes state in their book that the intestine of *S. meleagris* is very long and winds in the form of a double spiral.

B. Feeding Habits.

According to the report of Ishida, this fish feeds on sea-weeds all the year around.

133. *Enedrias nebulosus* (Temminck et Schlegel): Ginpo.

A. Digestive System.

Body elongate, greatly compressed posteriorly. Mouth small (m-c being ca. 1/5 and m-b ca. 5/26 of head length), directed slightly upwards; lower jaw trifly longer than the upper; teeth short, blunt, in narrow bands on both jaws. Mouth cavity small; a few minute teeth on the vomer; tongue medium in size, trianguloid, thick, smooth, free anteriorly, no melanin chromatophores. Pharyngeal teeth conical and numerous. Gill-rakers short (the length being ca. 1/6 of corresponding gill-filaments), pointed (some forked), 12 in number of average.

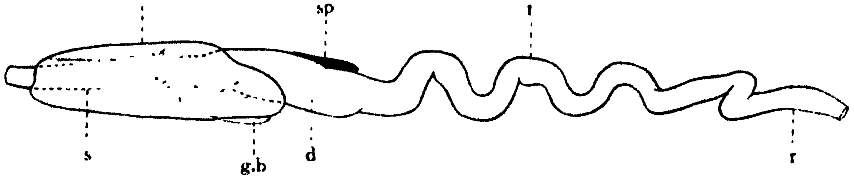


Fig. 169. *Enedrias nebulosus.*

Stomach I-shape, small, wall rather thick, folds of the mucous membrane longitudinal; stomach completely covered behind the liver. Duodenum wide; intestine narrow, winding zigzag or serpentine (such a winding-type being very rare); mucous membranes of the duodenum and intestine consist of net-work folds. Intestine is divided into the middle intestine and rectum by a valve. No pyloric appendage.

Liver rather large, consists of large right and left lobes; gall-bladder ellipsoidal; bile and cystic ducts short. Spleen small, located near the duodenum.

B. Feeding Habits.

I collected 5 of this fish 14.3 cm in average body length from the adjacent waters of Usima, Hukuoka Prefecture in July, 1936. They had taken mainly young fishes, or larval fishes.

134. *Dinogunellus grigorjewi* (Herzenstein): Nagazuka.

A. Digestive System.

Body elongate. Mouth large (m-c being ca. 2/3 and m-b ca. 5/7 of head length), lower jaw longer than the upper; teeth on jaws in bands; those in the upper jaw minute, those in the lower slightly larger. Mouth cavity rather small; palatal mucous membrane without folds; teeth on vomer small, blunt; those on palatines larger, irregular in size, the largest being about twice as long as the longest jaw tooth. Tongue large, triangular, smooth, no melanin chromatophores, thick, free. Teeth on the pharyngeal bones rather large and conical, curving in. Gill-rakers not developed and represented by a few small bunches of setae.

Peritoneal cavity rather slender; peritoneum silvery. Stomach large, ┤-shape, wall thick; mucous membrane consisting of about 12 longitudinal folds; cardiac part and blind sac wide, pyloric part narrow and short. Intestine moderately long (the length being ca. 2.5 times d~a), winds twice forming an N, rather narrow, wall thick, mucous membrane consisting of net-work folds; divided into the middle intestine and rectum by a valve. Pyloric appendages rather short, 5 in number.

Liver large, 2 lobes, the left being large and long, the right short and not as large, rather thick. Gall-bladder rather large, spherical; bile and cystic ducts both very short. Air-bladder located near the rectum, very small, ellipsoid.

B. Feeding Habits.

According to the fishermen of Samеminato, Awomori Pref., this fish is carnivorous.

Remarks:

Thus, the above is a description of the digestive organs and feeding habits of 3 species which belong to the family Blenniidae. But regardless of the fact that these 3 species come from the same family, there is quite a difference in the form of their gill-rakers, stomach and intestine; the existence and non-existence of pyloric appendages, etc., etc. It is very seldom that the internal organs of the species coming from the same family should vary like the present species and may be, in my opinion, a matter of importance from a systematic standpoint. Furthermore, the feeding habits of 1 of the species are herbivorous while the other 2 are carnivorous.

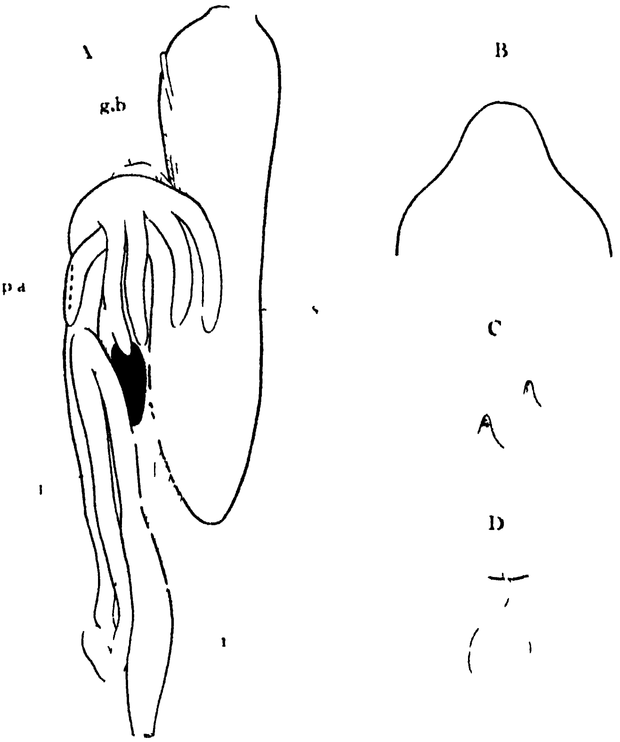


Fig 170. *Dinogunellus grigorjewi* A Digestive tract Ventral side B Tongue C Teeth on palatine D Gall bladder

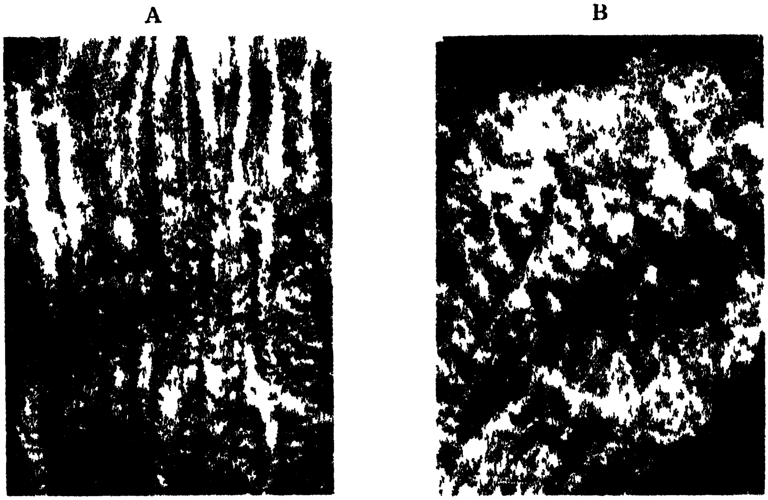


Fig 171 *Dinogunellus grigorjewi* A Folds of mucous membrane of stomach B The same of intestine

Family OPHIDIIDAE

135. *Otophidium asiro* (Jordan et Fowler): Asiro.

A. Digestive System.

Body elongate, compressed, the tail tapering to a point. Head oblong, compressed; snout rather blunt. Mouth large (m-c being ca. 1/2 of head length), directed obliquely upwards; lower jaw slightly included. Teeth in jaws rather small but pointed, grown in broad bands; a single series of small conical teeth in vomer; those on palatines villiform. Tongue very small and slender. Pharyngeal teeth as large as jaw teeth. Gill-rakers short (as long as corresponding gill-filaments), flat, tips pointed, 5 to 6 in number, process on each gill-raker numerous.

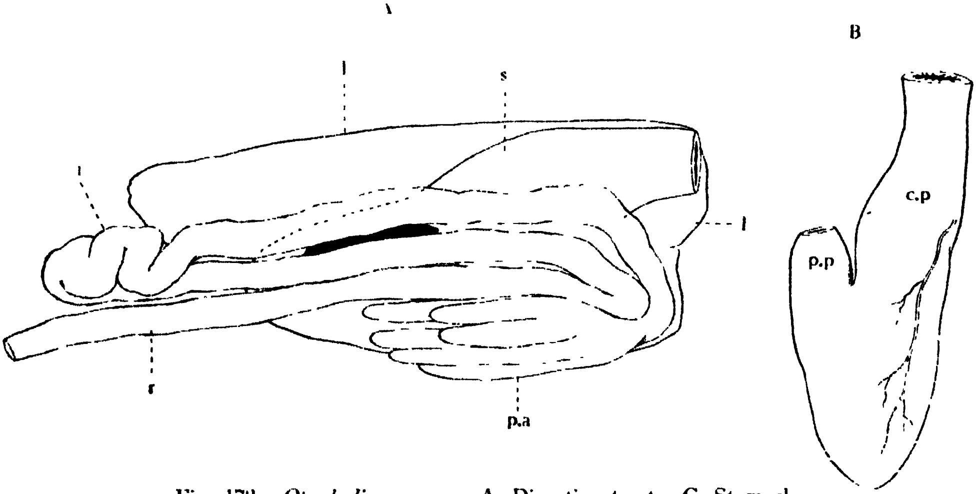


Fig. 172. *Otophidium asiro* A. Digestive tract. C. Stomach.

Peritoneal cavity rather small and elongate; a few melanin chromatophores on peritoneum. Oesophagus moderately broad and with thick wall, mucous membrane consists of 9 to 10 longitudinal wide folds. Stomach large, V-shape, wall thick, mucous membrane consists of longitudinal serpentine folds. Intestine rather long (the length being ca. thrice d~a), winds as shown in the figure, wall thin, mucous membrane consists of longitudinal folds of papillary processes. Rectum short. There is a valve between the intestine and the rectum. Pyloric appendages large and long, 11 in number.

Liver large, 2 lobes, left lobe far larger than the right; gall-bladder small and slender. Air-bladder short and thick and with a large foramen.

B. Feeding Habits.

I collected 14 fishes (30.8 cm in average body length) from the Mituhama Fish Market on Mar. 21, 1936, and 10 fishes from the Tyôsi Fish Market on Sept. 15, 1936. The former had taken the crabs, the shrimps (Pandalidae, Pasiphaeidae) etc., and the latter the crabs and the brittle-stars in their stomachs.

Family PLEURONECTIDAE

136. *Paralichthys olivaceus* (Temminck et Schlegel): Hirame.

A. Digestive System.

Body oval, strongly compressed. Eyes on the left side. Mouth large (m-c being ca. 5/13 of head length), oblique, cleft of mouth on the left and right sides almost of the same length but the right side of some is longer than the left. Teeth in each jaw large and conical, arranged in 1 row; those in the anterior part large but become smaller backwards, there being no great difference in the number at the left and right sides, besides which are numerous small hinged teeth. Mouth cavity narrow; palatal mucous membrane longitudinal folds; no teeth on vomer and palatines. Tongue almost triangular, transverse section triangular, thin anteriorly, free, soft and no melanin chromatophores. Upper pharyngeal teeth conical, well developed, the lower not so (they being merely felt coarsely on the hand, if felt). Gill-rakers rather long (as long as corresponding gill-filaments), flat, 20 in number of average, process on each gill-raker numerous.

Peritoneal cavity very much compressed; peritoneum silvery. Oesophagus short and wide, wall thick, mucous membrane consisting of about 18 longitudinal folds. Stomach large, ˥-shape but curves as illustrated, in the from of a bow; mucous membrane of the cardiac part consists of 8 to 9 longitudinal folds which run in short zigzags, grooves between the folds being deep and each groove consisting of fine longitudinal folds; mucous membrane of the blind sac longitudinal serpentine folds; pyloric part round and very small, connects with the duodenum by a valve. Intestine rather long and wide (the length being ca. 2.6 times d~a), the first part draws a ring and the rest from the middle bends in zigzag form, wall rather thick, mucous membrane petal-like folds. Intestine divided by a valve distinctly into the middle intestine and the rectum. Pyloric appendages broad and large, 4 in number, mesentery well developed,

Liver moderate in size, 2 lobes, the left being larger than the right, located approximately on the left side of the digestive tract. Gall-bladder large, spherical, located on the right of the pyloric part of the stomach; near the end of the gall-bladder are the islets of Langerhans. Bile duct long, opening to the duodenum. Around the stomach and along the mesentery are the pancreas, densely scattered.

As for the digestive system of this fish, Ôtaki (1897) who studied the Japanese Pleuronectidae, wrote a report on the teeth and gill-rakers of this fish, Okamoto (1918) on its stomach, and Hikita (1934) who made a study of flat-fishes in northern Japan, on its digestive organs. In Okamoto's report, the number of the pyloric appendages of this fish is given as 7 to 8, but I am inclined to think that this was due to a misobservation.

B. Feeding Habits.

According to Ôtaki (1897), this fish feeds on various fishes near the bottom, shrimps, and cuttle-fishes. When I examined the stomach contents of those

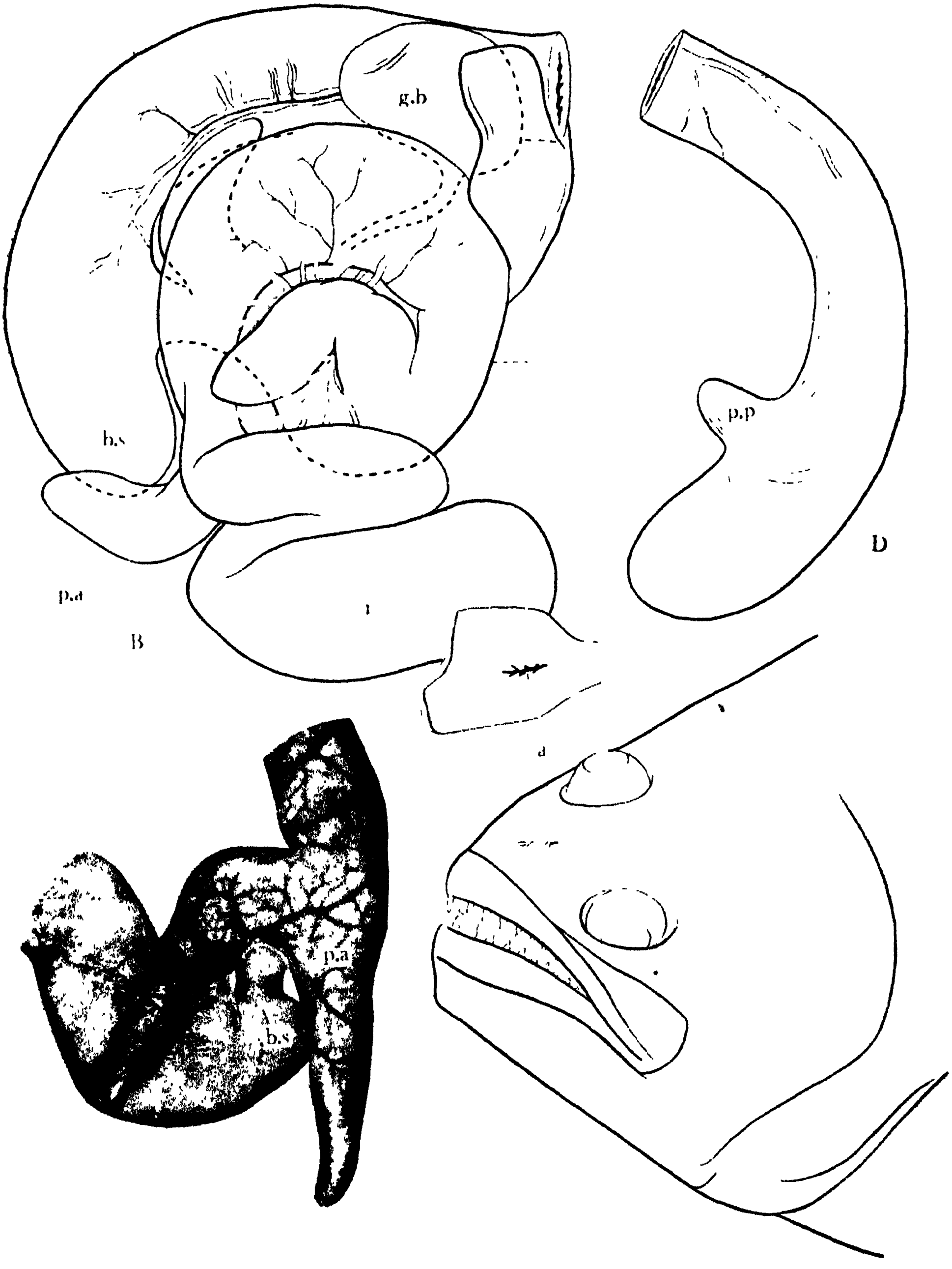


Fig. 173. *Paralichthys olivaceus.* A. Head. B. Digestive tract. C. Pyloric appendages. D. Stomach.

(10 of them, 9.0–12.7 cm in body length) caught on May, 17, 1936 and the 3 (9.9, 10.2, 10.3 cm) collected on January 10, 1939, I found that they had eaten a large quantity of cuttle-fishes and fish bones but hardly any trace of their having had shell-fishes, clam-worms, or brittle-stars that live in the sand at the bottom could be found. But in reading the report of Bigelow and Welsh (1925, p. 493) on the feeding habits of *Paralichthys dentatus*, one comes across the following description: " ...., feeding largely on small fish of all sorts, on squids, and likewise on crabs, shrimps, and other crustaceans, small shelled mollusks, worms and sand dollars", which means that it feeds also no small animals living at the bottom.

137. *Atheresthes evermanni* (Jordan et Starks): Aburagarei.

A. Digestive System.

In order to avoid duplication, I shall describe only the points which differ from those of the above species.

Eyes on the right side of the body; cleft of mouth on both sides, as in the above instance, almost of the same length, only the number and growth of the teeth differ somewhat, namely, in the lower jaws are 2 rows of conical on each side, in the upper 2 rows on the right and 1 on the left (the others being villiform teeth). The present species has more teeth than the above. Gill-rakers 10 to 14. Stomach also ˥-shape which curves in the form of a bow. Intestine extremely short, no zigzag turnings but winds round in the form of a circle and an N combined.

Liver 2 lobes, and regardless of the fact that its eyes are on the right side (when the body is laid down, the left and right of the body becomes vice-versa to the afore-mentioned species), the left lobe is larger as in the case of the above species, which is very interesting. The number of pyloric appendages is also 4, but 3 are big and 1 small.

B. Feeding Habits.

According to the examination of those (body length: 38.0, 97.5 cm) caught near Muroran by the Muroran Branch of Hokkaidô Fisheries Experimental Station (1929), cods, herrings, other fishes and fish bones were found in their stomach (although many of them had empty stomachs). It would therefore seem from these results that the principal food of this species is fish.

138. *Hippoglossoides elassodon* (Jordan et Gilbert): Umagarei.

I have already written a report on the digestive system and feeding habits of this fish (1934).

A. Digestive System.

That there are 17 to 20 gill-rakers is one of the slight differences of this fish when comparing it with the above 2 species. The approximately same length of cleft of mouth on both sides, the single row of jaw teeth, tongue, pharyngeal teeth, stomach, intestine, pyloric appendages, liver, etc. are also all approximately the same, and so I shall not describe them again. Eyes on the right side of the body; the type of intestinal winding similar to species 137.

B. Feeding Habits.

I examined the stomach contents of the 6 fishes which Mr. H. Higasi collected on June 28, 1933 from the Bering Sea (25.7–28.6 cm, ♀ : ♂ =2 : 4) and found that they had eaten Crustacea (chiefly *Crago*) and Echinodermata (chiefly *Ophiura*). No shell-fishes, clam-worms, or sand particles were found.

139. *Lepidopsetta mochigarei* (Snyder) : Asabagarei.

A. Digestive System.

Eyes on the right side. Mouth on the right side small, oblique (m-c being 1/7 to 1/8 of head length) ; right cleft of mouth longer than the left. Lower jaw longer than the upper. Jaw teeth conical and blunt, in a single row, those in the left side numerous and large and those in the right few and extremely small. Tongue almost triangular, thin anteriorly, free, soft, no melanin chromatophores. Pharyngeal teeth conical, bearing a strong resemblance to the jaw teeth. Gill-rakers short and coarse, approximately 10.

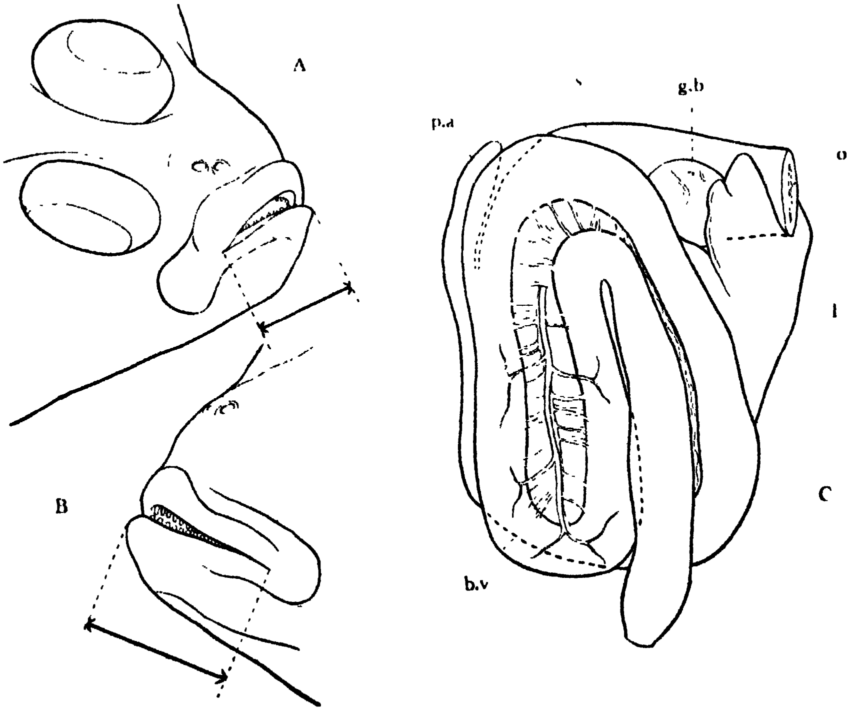


Fig. 174. *Lepidopsetta mochigarei*. A., B. Mouth. C. Digestive tract.

Peritoneal cavity small and compressed; peritoneum silvery. As in the above 3 species, stomach takes the form of a curved I-shape and not ˥-shape due to the absence of the pyloric part and blind sac; wall moderately thick, mucous membrane longitudinal serpentine folds. Intestine moderately long (the length being ca. 2.4 times d~a), the first part forming a circle and the latter part the letter N, wall thick, mucous membrane, petal-like papillae which grow irregularly and longitudinally. Succeeding the stomach are 4 rather small pyloric appendages.

Liver not large, weighing about 1/47 of the body weight, consists of 2 lobes. Gall-bladder large, almost spherical; cystic duct rather long. Pancreas may be found scattered around the pyloric appendages and along the mesentery.

B. Feeding Habits.

For detailed information, please refer to the report which I have already written in 1934.

An examination of those caught in 4 different places at different times in the North Pacific showed the following results: they had eaten small animals which live at the bottom, such as *Aega* that comes from the family Isopoda, certain Amphipoda, Crustacea such as Cumacea and Eupaguridae, Pelecypoda such as *Yoldia* or *Cardium*, Echinodermata such as *Ophiura*, and Polychaeta such as *Glycera* or *Nereis*, etc. They had not eaten any fish or large Crustacea.

Table 39

Stomach contents of *Lepidopsetta mochigarei*

Date	June 28, 1933	Aug. 11, 1930	Aug. 12, 1930	June 14, 1932	Frequency
Locality	Bering Sea	Adjacent waters of Syumusyu Island	Adjacent waters of Alaska	Adjacent waters of Sibotu Island	
Number of fish	27	2	3	6	
Av. body length (cm)	27.4	28	22	21.9	
♂ : ♀ Stomach contents	13:14	0:2	2:1	3:3	
Bones of small fishes			1		1
Pinnixa tubicola	2				2
Cumacea	3	2			5
Amphipoda	6	1		1	8
Eupagurus	3				3
Isopoda	1	1	1		3
Aega	2			4	6
Nucula	1				1
Yoldia	15		1		16
Cardium		1		1	2
Serpula				1	1
Polychaeta	13	1	2	1	17
Glycera	2				2
Nereis				1	1
Ophiura	2		1	1	4
Spatangoidea	4		1		5
Sand particles	23	2	2	4	31
None				1	1

140. *Limanda Yokohamae* (Günther): Makogarei.

A. Digestive System.

Eyes on the right side of body. Cleft of mouth on the left side longer than the right. Jaw teeth on the left side large and numerous, those on the right degenerate. Gill-rakers short and small, about 10. Stomach a bow-shaped I; hardly any difference in the digestive system in comparison with the previous species (No. 139); pyloric appendages 8 to 13 (note that the number of pyloric appendages for a fish from the family Pleuronectidae is usually 4).

B. Feeding Habits.

According to Ôtaki, (1897), this fish takes for its principal food certain shrimps, crabs, clam-worms, brittle-stars, shell-fishes fish, etc.

141. *Kareius bicoloratus* (Basilewsky): Isigarei.

A. Digestive System.

Eyes located on the right side of the body. Mouth small (m-c being ca. 1/5 and m-b ca. 3/20 of head length), oblique; cleft of mouth on both sides approximately the same, the left being slightly longer. Jaw-teeth in 1 row, incisor-like and numerous, more in the left side than in the right. No teeth on vomer and palatines. Tongue large, triangular, free anteriorly, no teeth and melanin chromatophores on the surface. Pharyngeal teeth almost the same as the jaw teeth; according to Hikita, (1931, p. 194), those on the upper pharyngeal bones number I-6 to 12, II-12 to 27, and III-3 to 10. Gill-rakers strong and short (the length being ca. 1/4 of corresponding gill-filaments), tips pointed, in average 8.

Stomach wide, a bow-shaped tube, having no blind sac or pyloric part, wall thick, mucous membrane consisting of 12 to 14 longitudinal serpentine folds. Intestine longer than the above 2 species (the length being ca. 2.6 times d~a), the type of winding being similar to that of *Paralichthys olivaceus*, wall rather thick, mucous membrane being longitudinal folds constituted by papillary process (Pl. XII, Fig. 30). A valve divides the stomach and intestine and the intestine and the rectum. Pyloric appendages small, numbering 2 to 3. Mesentery well developed.

Liver 2 lobes, the left being larger than the right. Gall-bladder large and spherical; bile duct long.

B. Feeding Habits.

According to Ôtaki (1897), this fish lives principally on clam-worms, shell-fishes, small shrimps and sardines; small animals which live at muddy bottoms.

Remarks.

According to Hikita (1934), species No. 136, No. 137 and No. 138 belong to the sub-family Hippoglossinae and No. 139, No. 140 and No. 141 to the sub-family Pleuronectinae, but there is an interesting difference in the digestive system of these 2 sub-families; that is, cleft of mouth on both sides (sides with and without eyes), for the former 3 species is almost the same length, but the cleft on the side without eyes for the latter 3 is longer than the side with eyes; number of jaw teeth in both sides of the former almost the same,

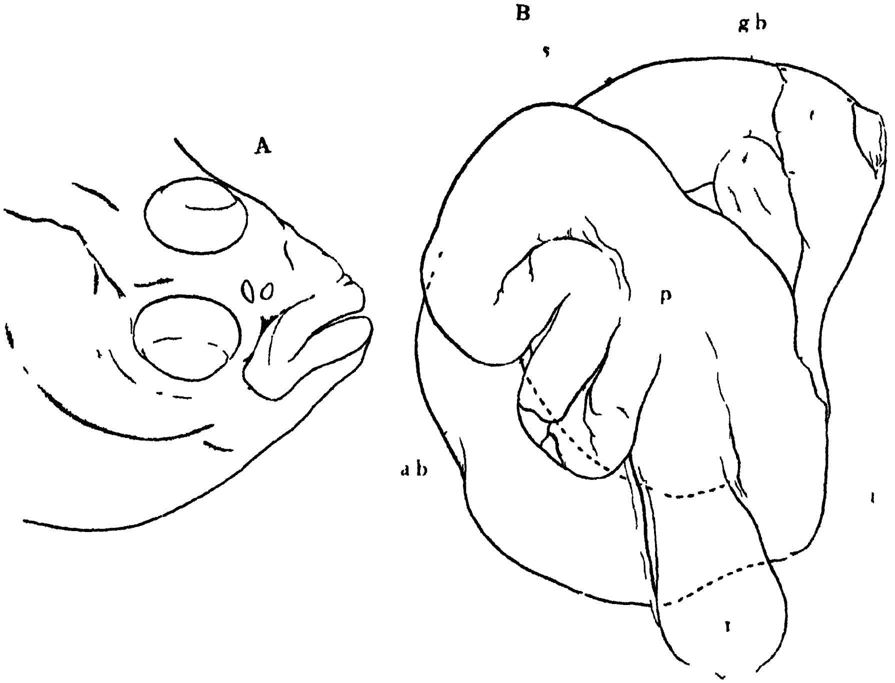


Fig 175 *Kareius bicoloratus* A Head B Digestive tract

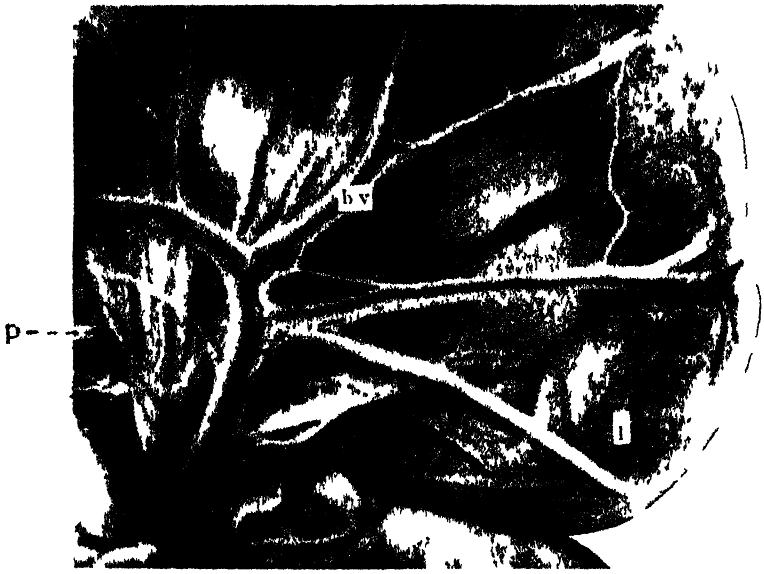


Fig 176 *Kareius bicoloratus* A part of intestinal tract, showing the pancreas

but the latter has more in the side without eyes. Stomach of the former ˥-shape and the latter I-shape (this is worth nothing). Regardless of whether the liver is located to the left or right of the eyes, the left lobe is always larger than right. And it would seem that the latter 3 are much more genuine bottom feeders than the former 3 species.

Regarding the study of the digestive systems of Pleuronectidae, as already stated in the foregoing pages, Cole's (1901) work requires special mention. He made a very detailed anatomical study of *Pleuronectes platessa*. In addition to his work, there is the work of Cuvier (1810) who studied the digestive tract of *Hippoglossus vulgaris*, *Limanda limanda*, and others, and the reports of Rathke (1824), Meckel (1829), Eggeling (1908), Jacobshagen (1911), Dawes (1929), and Pernkopf (1930), on the digestive organs of various foreign flat-fishes. Dawes made a histological observation and found that the intestine and pyloric appendages were similarly constructed.

In connection with the feeding habits of Pleuronectidae, we cannot overlook the report made by Franz (1910). He examined the stomach contents of many *Pleuronectes platessa* from the North Sea and discovered that it chiefly ate Pelecypoda, Ophiuroidea and *Nereis*. Bean (1889), T. Scott (1911) and Hertling (1928) studied the feeding habits of adult flat-fishes and Linton (1921) made a study of the young. Mortensen (1897) and Petersen (1910, 1911) accomplished an important study on the migration of flat-fishes and bottom food.

Family CYNOGLOSSIDAE

142. *Rhinoplagusia japonica* (Temminck et Schlegel): Kurousinosita.

A. Digestive System.

Eyes on the left side of body. Body broad-ovate, very much compressed. Mouth small, terminal, curved and unsymmetrical. Hook of upper jaw very long. Tentacles on lips of left side (no tentacle on the right side). Small conical teeth in bands on jaws of right side; teeth on the right degenerated. Mouth cavity small and compressed. Tongue medium in size, semi-elliptic, thick, free anteriorly, black in colour. Pharyngeal teeth conical, larger than jaw teeth, especially those on upper pharyngeal bone large. Gill-rakers completely degenerated.

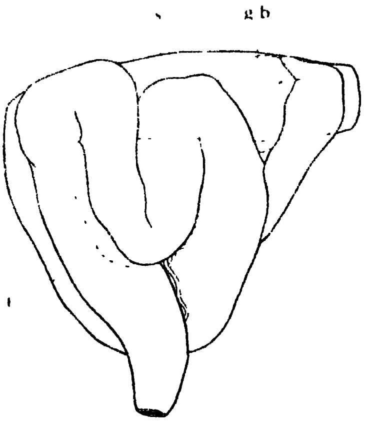


Fig. 177. *Rhinoplagusia japonica.*

Peritoneal cavity very small and compressed; peritoneum silvery. Oesophagus short, folds of mucous membrane longitudinal. Stomach merely a cylindrical tube, rather broad, mucous membrane consists of longitudinal serpentine folds. Intestine moderately long (the length being ca. 4/5 of body length), first drawing a circle, makes 1 turn and then bends in a zigzag manner. Its mucous membrane consists of numerous small papillary processes. No valve between stomach and intestine. No pyloric appendage.

Liver 2 lobes, left lobe large while the right small; gall-bladder large and spherical, located between the cardiac part of stomach and the right lobe of liver. Bile duct long, opens at the beginning part of duodenum. Mesentery and pancreas well developed around the intestine.

B. Feeding Habits.

I could not obtain enough samples to ascertain the feeding habits of this fish. However, Ehrenbaum (1936, p. 230) says on the natural food of *Solea vulgaris* which is rather closely related to my sample " Als Nahrung spielen die grösste Rolle verschiedene Borstenwürmer (bes. *Pectinaria auricoma*), demnächst Kruster verschiedener Familien (*Crangon*, *Portunus*, Amphipoden, Isopoden, Mysideen, Cumaceen, bes. *Diastylis*), ferner Muscheln (*Solen*, *Syndasmia*, *Mactra*, *Donax*), weniger Stachelhäuter (*Echinocyamus*, *Ophiothrix*) und noch weniger Fische (*Ammodytes*, *Gobius*, *Rhombus*, *Pleuron*, *Limanda* und *Amphioxus*)." According to Couch (1864, p. 201), sole usually seeks its food only by night.

143. *Areliscus joyneri* (Günther): Akasitabirame.

A. Digestive System.

The differences in the digestive system of this fish in comparison with the above-mentioned fish are as follows:--

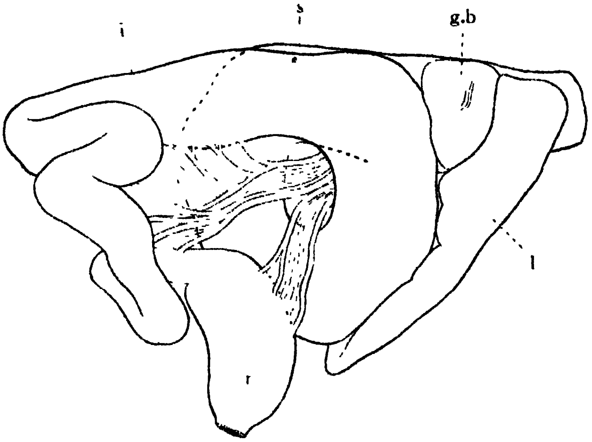


Fig. 178. *Areliscus joyneri.*

No tentacles about the mouth; tongue not black, stomach grey from outside; intestine slightly longer than the above-mentioned species, accordingly, the winding type of the intestine of this fish differs somewhat to that of the above species; right lobe of liver rather long.

B. Feeding Habits.

I do not think that there is a great deal of difference in the feeding habits of the present species and those of the above-mentioned species.

Family GADIDAE.

144. *Gadus macrocephalus* (Tilesius): Tara.

I have already made a report (1934) on the digestive system and the feeding habits of this fish.

A. Digestive System.

Body elongate, compressed, somewhat ovate. Mouth large (m-c being 1/3 and m-b 1/2.7 of head length), slightly oblique upwards, upper jaw projecting slightly than the lower, jaws not protrusile; 1 pair of barbels in the lower jaw, the length of which being a little longer than the diameter of the eye. Teeth in upper jaw consist of 4 rows of pointed conical teeth, the outside row being the largest and the teeth of the 3 inner rows being small; teeth in lower jaw are also pointed conical but only 1 row of them. On the vomer, there is a group of teeth forming the letter V, which teeth are about the same size as the minute teeth in the upper jaw. They are all hinged teeth. Matuno (1924) has already written a report on the teeth, etc. of this fish, but the report was simple and gave no description of the hinged teeth. Buccal cavity unusually large; Plicae palatinae consisting of some 30 or 40 fine longitudinal folds; melanin chromatophores on the buccal mucous membrane lacking entirely. Tongue moderately large, semi-elliptic, rather thick, free, tip rather soft, smooth surface, small papillae exist scattered, no melanin chromatophores. Both upper and lower pharyngeal teeth pretty well developed, the upper pharyngeal teeth consisting of 20 to 50 small conical teeth on each of the 3 sets of pharyngeal bones, the teeth curving in: the lower consist of a pair group of teeth forming a pair of half-moon, the size of the teeth being about the same as the upper. Gill-rakers flat and oblique to the gill-arch, moderately long (2/3 of corresponding filaments), thick at the beginnings and pointed at the tips, coarsely grown, 18 to 22 in number, process none whatever.

Peritoneal cavity large; peritoneum black. Oesophagus thick and short, wall thick, mucous membrane consisting of about 50 fine longitudinal folds. Stomach a big sac, ┤-shape. Cardiac part and the blind sac are not distinct from one another but a slight difference in the mucous membrane, that is, the folds of the mucous membrane of the cardiac part meander and longitudinal, while the blind sac (it might be more appropriate to call it fundus of stomach, viz., Fundus ventriculi) is a net-work. Pyloric part is rather a long narrow tube, situated below the stomach, the cross section circular, wall thicker than the former, mucous membrane being indistinct longitudinal folds. Development of blood vessels conspicous on the stomach. Duodenum not exceptionally wide as may be seen in some species of fish, it is rather narrow. Boundary between duodenum and middle intestine is not clear. Middle intestine being a narrow tube, winding in a characteristic way. The total length

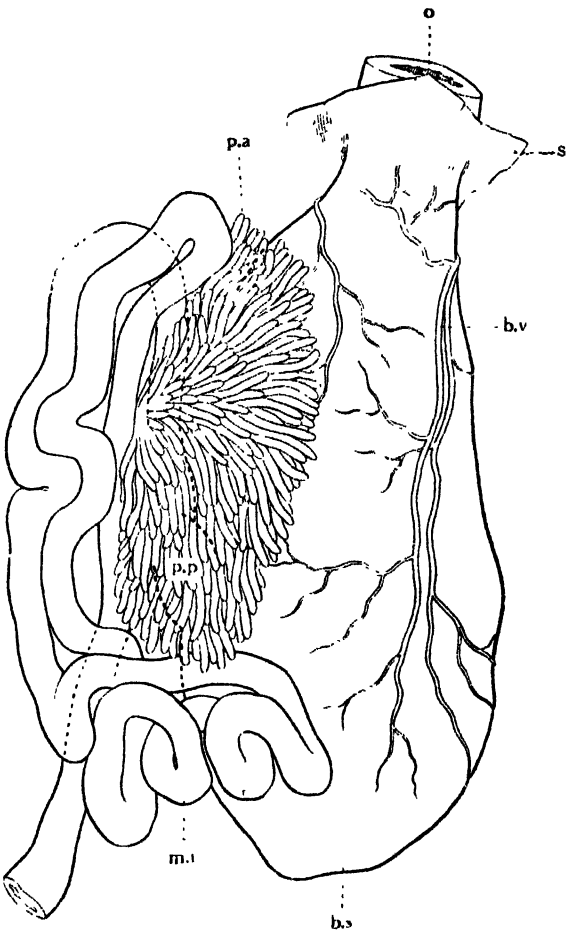


Fig. 179. *Gadus macrocephalus.* Left ventral side.

of the intestine is a trifle shorter than the body length and 2.6 times as long as o~a; wall rather thick, mucous membrane being indistinct longitudinal folds. Mesentery poorly developed. Anus situated just in front of the anal fin. Pyloric appendages rather short and fine, located below the stomach to the left in clusters, 380 in average number (Matsuno (1924) reported as 550).

Liver large, embracing the oesophagus from below, consists distinctly of 3 lobes, the right, middle, and left, of which the right is the longest; Lobus quadratus also present, rather thick, hepatic artery broad. Gall-bladder ellipsoid; Ductus choledochus moderately long, opens at the beginning of the duodenum. Pancreas scattered chiefly between the clusters of the pyloric appendages. Islets of Langerhans large, located at the end of the gall-bladder. Spleen rather long, narrow and thin. Air-bladder a big sac with thick wall.

Regarding the digestive system of genus *Gadus*, as stated above, Matuno

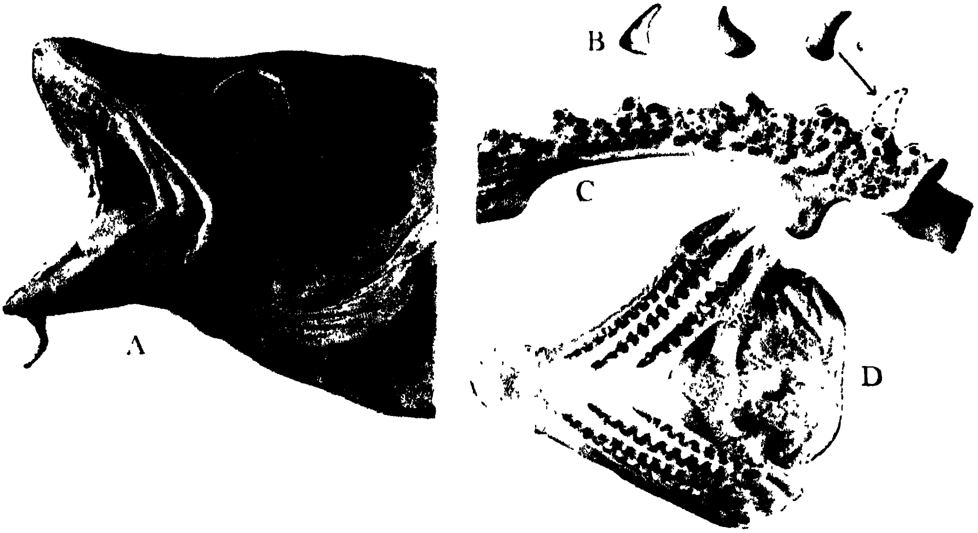


Fig. 180. *Gadus macrocephalus*. A. Head B., C. Hinged teeth. D. Gill and tongue.

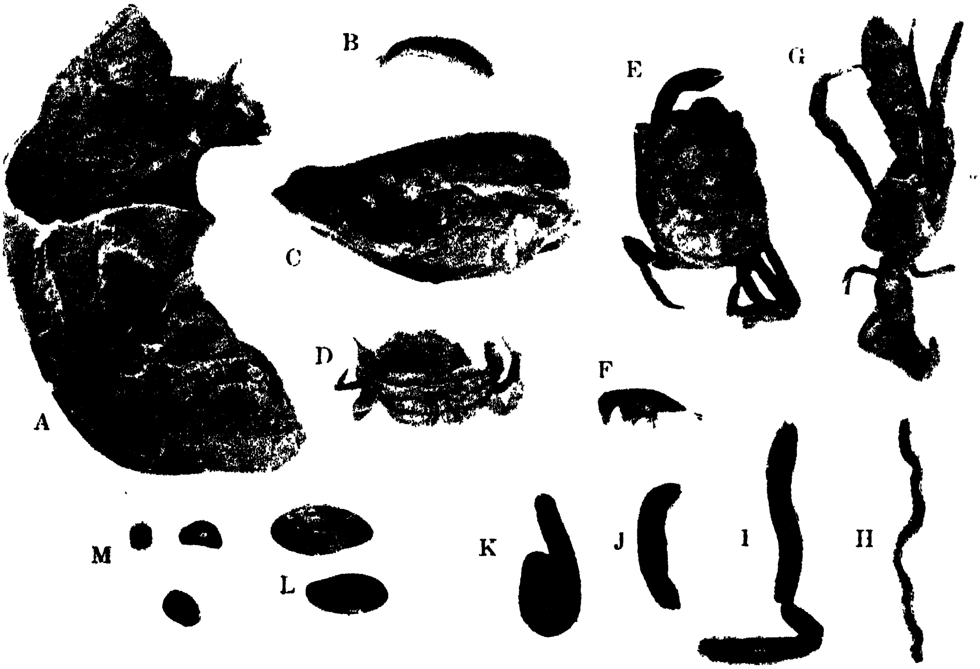


Fig. 181. Stomach contents of *Gadus macrocephalus*. A. Flat-fishes and crabs in the stomach. B. Certain fish. C. Skull of *Theragra chalcogramma*. D. Certain crab. E. *Hyas coarctatus*. F. *Anonyx*. G. *Eupagurus*. H., I., J., K. Polychaeta. L. *Yoldia*. M. Andesite grains.

made a report on the teeth, pyloric appendage, etc. of *Gadus macrocephalus*, while I studied the whole digestive system of this fish. Besides these studies, Haller (1904) wrote a report on the teeth of *G. morrhua*; Rathke (1824) and Jacobshagen (1911) on the digestive tract of *G. callarias*; Home (1814) on the digestive tract of *G. aeglefinus*; Rudolphi (1802) and Meckel (1829) on the digestive tract of *G. morrhua*.

B. Feeding Habits.

From my examination of the stomach contents of fishes caught in Bristol Bay on June 20, 1933 and those collected on February 1, 1938 at the fish-market of Sameminato, Aomori Prefecture, as shown in the Table 40, I found that they consisted of fishes, such as halibuts, herrings and cods, of mollusca like the octopus, of shell-fishes like *Yoldia*, of Crustacea such as *Hyas*, *Pinnixa*, *Eupagurus* and *Crago* and Polychaeta, as also stones which were often found among them. The stomachs were all stuffed with food and not one of them empty.

In going over the papers hitherto written, there were reports in this connection by Marukawa (1919) to the effect that the Suketodara (*Theragra chalcogramma*), halibuts, trouts and other fishes, as also many crabs and shrimps, were among the stomach contents of the cod caught in the nothern waters of the Pacific; by Trachmann (1889) who was astonished to find 14 *Gadus merlangus* of from 4 to 5 inches in body length in the stomach of one *Gadus aeglefinus* which itself was only about 17 inches long; by Sharp (1901) who reported that English cods had their stomach filled with bottom food, such as crabs and shell-fishes; by Paulsen (1918) who stated that *Gadus callarias* fed on bottom creatures and cods; by Franz (1919) who examined 7 species of the cod and came to the conclusion that their main food consisted of fishes of their own family, and herrings and bottom animals; by Hickling (1928) who examined 955 *Merluccius vulgaris* and reported that 434 *Gadus poutasson* had been eaten among them; Zenkevich (1931) who examined the stomach contents of the cod in the Barents Sea all the year round and made an important report. He said that although its chief food consisted principally of fishes, it supplemented its food, where it was insufficient, with planktonic Crustacea. Meschkat (1936) who made a detailed examination of the stomach contents of 1245 cods caught near Vestmanna, expressed the opinion that although fishes (herrings, etc.) and Crustacea were their principal food, they were voracious omnivora.

Thus, it will be seen from the reports of many scholars and the studies which I have made that this fish, the cod, may be classified with the carnivorous and voracious fish, and that it goes not only in hot pursuit of bottom animals but it delights in devouring the fishes of its own family and herring.

Regarding the food of the young of this fish, Miyahuzi (1914) made a study with material caught in Chôsen waters. According to him, they (over 3 cm) feed chiefly on copepods and diatoms.

145. *Theragra chalcogramma* (Pallas): Suketôdara.

A. Digestive System.

Other than that the present fish is smaller than the above mentioned species of the entire Gadidae family, they bear the closest resemblance to one another. However, insofar as the digestive system is concerned, there are not a few points in which they differ, and it is about their differences that I wish to take up here.

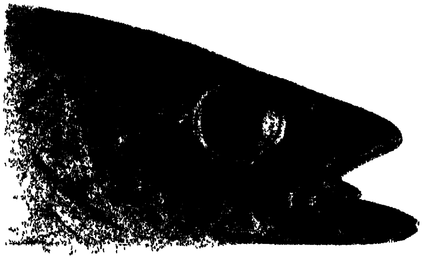


Fig. 182. *Theragra chalcogramma.*

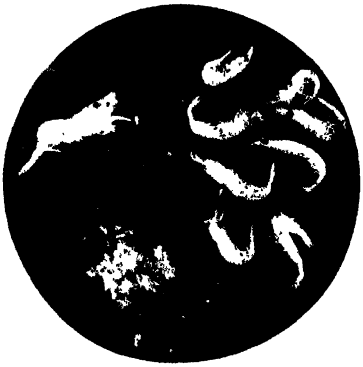


Fig. 184. Stomach contents of *Theragra chalcogramma.*

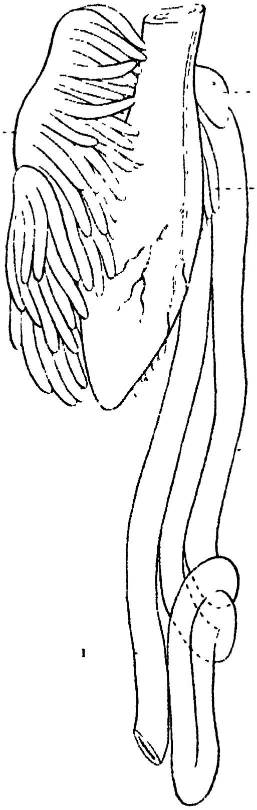


Fig. 183. *Theragra chalcogramma.* Dorsal side.

In the first place, the barbels are much shorter and the cleft of mouth smaller than that of the foregoing species. In the previous case, the upper jaw was longer than the lower but in this case, it is vice-versa. The shape of the tongue is very much alike too, only that of the former was larger; the location of the teeth is very much the same in both instances, except the teeth of the previous species were larger. The gill-rakers are also longer and grow more thickly, 38 in average number, while the previous species had an average of 21. The stomach of the present species is much smaller and the distribution of blood vessels on the surface much less, the intestine being almost the same. The pyloric appendages are longer and thicker, 91 in average which is about 1/4 of the previous species. Contrary to the liver of the foregoing species being thick and large, the present one is neither large nor thick but rather thin (the former weighing ca. 1/20 and the latter ca. 1/36 of the body weight).

B. Feeding Habits.

It is very interesting to compare the feeding habits of this fish with those of the previous one. The present species, as may be seen from the table, feeds chiefly on planktonic Crustacea, and it is worth noting that it is not of the voracious species. It is also interesting to note that from observation of their stomach contents, it can be seen that the previous species lives principally near the bottom of the sea while the present one has its habitat nearer to the surface. At the same time, it will be seen that the difference in the digestive organs, to begin with the barbels, reflects directly on their feeding habits.

Table 40

Stomach contents of *Gadus macrocephalus* and *Theragra chalcogramma*

Species		„	*Gadus macro-cephalus*	*Theragra chalco-gramma*
Date		Feb. 1, 1938	„	June 20, 1933
Locality		Same-minato, Awomori Pref.	„	Bristol Bay
Number of fish		10	15	25
Av. body length(cm)		38	42	39.9
Stomach contents	Av. body weight(g)	—	1039	633
Fishes	*Theragra chalcogramma*		3	
	Limanda aspera		1	
	Flat-fishes	2	2	
	Herring	3		
	Certain small fishes		2	
	Bones of fishes		2	
Crustacea	*Crago*		1	
	Certain small shrimps	2	2	3
	Hyas coarctatus		2	
	Pinnixa tubercola		5	
	Anonyx sp.	1	1	3
	Thysanopoda			8
	Certain amphipods		3	
	Spirontocaris sp.			2
	Eupagurus pubescens		1	
	Certain Paguridae		3	
	Calanus plumchrus			11
Polychaeta	*Glycera* sp.		2	
	Certain Polychaeta	1	2	
	Certain octopus	4		
Shell-fishes	*Yoldia* sp.		1	
Minerals	Andesite		4	
	None	3		5

146. *Eleginus navaga* (Kölreuter): Komai.

A. Digestive System.

Mouth large; barbel very short; upper jaw longer than the lower. Jaw teeth small and conical, 2 to 3 rows in upper jaw and 1 row in the lower. Mouth cavity rather large; folds of palatal mucous membrane concentric semi-elliptic. Tongue moderately large, thick, free, no teeth and melanin chromatophores on the surface. Pharyngeal teeth similar to those of cod. Gill-rakers rather long (a little shorter than corresponding gill-filaments), slender, tips pointed, rather closely set, 16 to 17 in number.

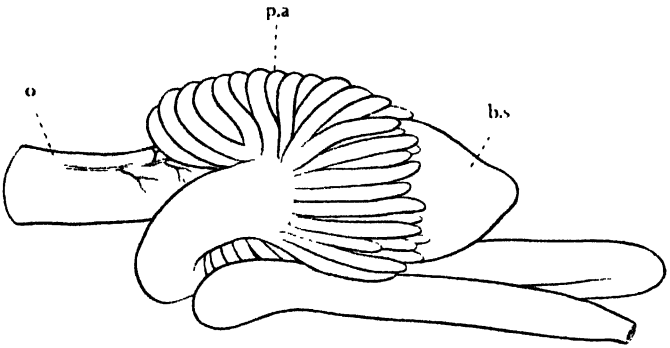


Fig. 185. *Eleginus navaga.*

Peritoneal cavity rather large; peritoneum silvery. Oesophagus rather long, mucous membrane consists of 25 longitudinal folds. Stomach moderately large, V-shape, wall thick, mucous membrane assumes 10 longitudinal folds. It is worthy of note that the blind sac is rudimentary. Intestine rather short (the length being ca. 2/3 of body length and thrice d~a), wall moderately thick, winds N-form; intestine divided by a valve into the middle intestine and the rectum. Folds of the mucous membrane of intestine similar to those of *Gadus macrocephalus.* Pyloric appendages broad and long as shown in the figure, 63 to 67 in number.

Liver rather large, 2 lobes, left lobe larger than the right, hanging over the oesophagus and the anterior part of stomach; gall-bladder small, located near the pyloric part of stomach.

Cuvier and Valenciennes report in their book that the intestine of *E. macrovinus* winds twice.

B. Feeding Habits.

According to the report of Takayasu and others (1930), the fishes which were obtained from Tôhutuko, Hokkaidô in summer had taken *Mysis* in their stomach.

147. *Lotella phycis* (Temminck et Schlegel): Isoainame.

A. Digestive System.

Body elongate, slightly compressed. Mouth large (m-c being ca. 2/5, m-b ca. 1/2 of head length); jaws equal; chin with a barbel. Teeth in narrow bands in jaws, outer series enlarged. Vomerine and palatine teeth none. Tongue very large, semi-elliptic, thin, free, without teeth and melanin chromatophores. Pharyngeal teeth similar to those of cod. Gill-rakers very short, tips pointed, coarse, 10 in number of average.

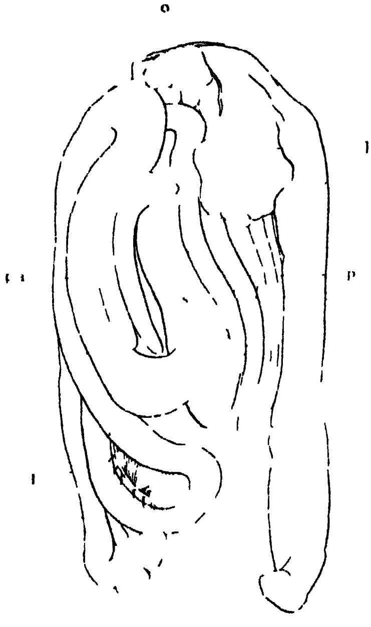


Fig. 186 *Lotella phycis* Ventral side

Peritoneal cavity large, oval; a few melanin chromatophores on peritoneum. Oesophagus short with thick wall. Stomach ┤-shape, moderately large, wall thick. Folds of the mucous membranes of cardiac part and pyloric part longitudinal, while those of blind sac crossed. Intestine rather long (the length being ca 4 times d~a), winds twice, drawing the letter N, wall rather thick, mucous membrane consists of branched folds (Pl. XII, Fig. 32). Pyloric appendages long and broad. 12 in number.

Liver 3 lobes, the left and the right lobes very long stretched; gall-bladder, a long sac, located behind the right lobe; bile and cystic ducts short. Air-bladder rather large, wall thick.

B. Feeding Habits.

When I examined the stomach contents of 10 fishes (14 to 15.2 cm in body length) caught off the coast of Yokosuka on May 4, 1936, I found that they had eaten bottom-living animals, especially the bottom-fishes, but according to the investigation made by Mizuno (1937) who examined those (4 of them: 14.5, 15.0, 15.9, 16.6 cm in body length) caught off the coast of Hayama, Kanagawa Pref., on the night of April 10, 1937, it was found that they had specialized in young Ayu. It would therefore seem that these bottom-fishes come up to the surface at night and attack the fishes that are near the surface.

Family LOPHIIDAE

148. *Lophius litulon* (Jordan): Kiankô.

A. Digestive System.

Body contracted; head wide, depressed, very large. Mouth exceedingly large (m-b being ca. 2/3 of head length), directs upwards owing to the lower jaw being much longer than the upper. 4 long separate spines on the dorsal side of the body and long filaments thickly set the mouth and other places. Majority of jaw teeth are hinged teeth, large and pointed, facing toward the throat; upper jaw teeth being irregular in height and arrangement and the lower arranged in 2 rows. Mouth cavity depressed but very large; palatal mucous membrane white. Smaller teeth than the jaw ones adorn the vomer, palatines and pharyngeal bones. Tongue large, crescent, smooth, free, melanin chromatophores rather thickly distributed, rather hard, and moderately thick. No gill-rakers whatever.

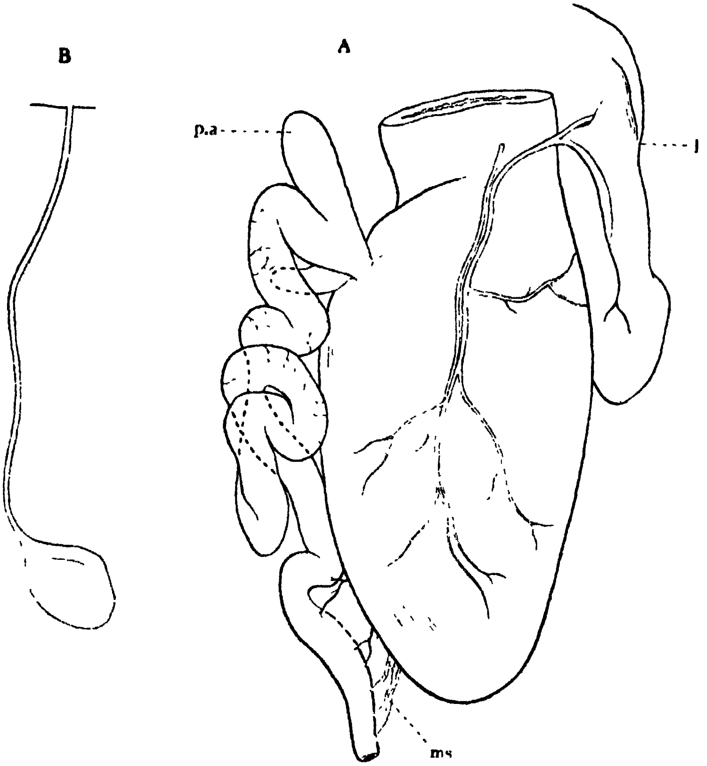


Fig. 187. *Lophius litulon.* A. Digestive tract. Ventral side. B. Gall-bladder.

Peritoneal cavity rather large, depressed; no melanin chromatophores on the peritoneum. Oesophagus wide, wall thick, folds of the mucous membrane longitudinal. Stomach very large, ┤-shape; blind sac especially large; pyloric part especially small. Wall of stomach thick; mucous membrane consisting of fine serpentine and numerous longitudinal folds. Contrary to the big stomach, the intestine is extremely narrow and rather long (the length being ca. 1.5 times d∼a), wall rather thin, making several short turns; mucous membrane with longitudinal folds, somewhat similar to network, divided distinctly into the middle intestine and rectum by a valve. Mesentery well developed. Pyloric appendages 2 in number, one big and long, the other small and short.

Liver rather large, weighing 1/24 of the body length and consisting of 2 imperfect lobes, the left being larger. Gall-bladder large, spherical; cystic duct long. Pancreas branches out on the mesentery, and there are several large and small islets of Langerhans on it too.

As regards the digestive system of Lophiidae, aside from the work of Cuvier (1810) who examined the digestive system of *Lophius piscatorius*, Meckel (1829), Eggeling (1908), Jacobshagen (1911) and many others made a study of it. The stomach is big, the pyloric part is especially small, the intestine winds several times, and it has 2 pyloric appendages, etc., all of which are similar to the characteristics of *L. litulon*. Walther (1915) studied the digestive organs of *L. piscatorius*, 14 mm to 50 mm in body length, and completed a very interesting study on its morphological and histological change. It must be borne in mind that the islets of Langerhans of fishes were first discovered in *Lophius* by Diamare (1899).

B. Feeding Habits.

Regarding the feeding habits of this fish, Wilson (1937) recently wrote an excellent report on this subject, synthesizing the many reports hitherto written thereon, together with his own work. In introducing his work, I shall also endeavour to introduce the work of other people whom he did not mention.

Since the work of Aristotle, many reports have been written up to the end of 19th century, but hardly any of them give accurate information. However, a number of those written after the 19th century have substantial information in them. Guitel (1891) states that from his observation of an angler fish 60 cm long in an experimental tank at Arago for 2 months, he did not see it once moving the lures on its head to entice the fishes which were to become its food nearer to its reach. But Bigelow and Welsh (1924) writing on the observation conducted by Clark state that the angler fish has been seen to hide itself among sea-weeds and, moving its lures, catch and eat the fishes which approach the lures. The most recent important report is the one made by Chadwick (1929). He made a very accurate observation of the angler fish cultured in an aquarium in Port Erin. He writes that he often saw it moving its lures and, enticing *Gadus virens* nearer to itself, swallowing them whole from the head. Although a popular sort of article, Weller (1934) states that he saw angler-fishes enticing the flat-fishes nearer to them with their lures and eating them. Wilson himself observed 10 angler-fishes cultured in an aquarium in Plymouth for 2 years (1935–1936) and saw them using their lures to attract fishes which were to be their food. He reports fully on how fishes are attracted by the lures of the angler fish and how the angler-fish catches the fish which approaches its mouth. He also states that it is not so voracious in its feeding habits as it looks (having an extremly large mouth, it was hitherto thought very greedy and ravenous).

As for the natural food of the angler-fish, Fulton (1903) examined 541 stomachs of fish caught in Aberdeen Bay and off the coast of Shetlands and found half the number with empty stomachs (perhaps, it was due to the length of time which elapsed after they were caught), while the remaining half were found to have eaten cuttle-fishes and Crustacea besides other fishes. 70% of the food eaten constituted fishes, cods, sand-lances, herrings, etc., while the balance of 30% constituted flat-fishes. I have already written about the curious feeding habits of *Cehatias* and shall not therefore remark on them here again.

The above studies all have to do with the foreign angler-fish. There are very few literature on Japanese angler-fishes. Tanaka (1916) states that he does not think that the lures of the angler-fish serve the purpose of attracting fishes. In February 1936 there was an article in the Tokyo Niti-niti Sinbun to the effect that Mr. T. Okazaki, a fishmonger in Higasi-Ryôgoku, Honzyô-ku, Tokyo, found a whole sea-bird on cutting open the stomach of a big angler-fish from Kamaisi.

Family ANTENNARIIDAE

149. *Pterophryne histrio* (Linne) Hanaokoze.

A. Digestive System.

Body not elongate, more or less compressed, soft, no scales, covered with a smooth granular skin. Head small, and mouth comparatively large; cleft of the mouth directing up-

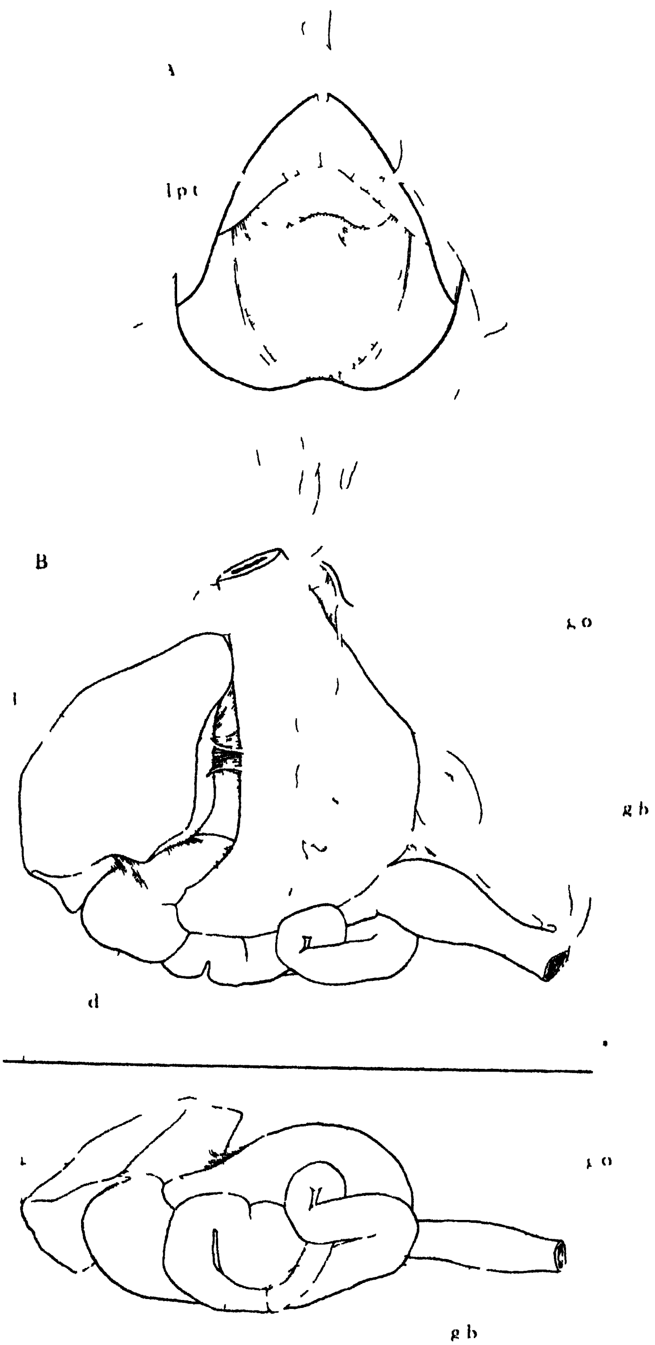


Fig 188 *Pterophryne histrio* A Mouth and pharynx B. Lateral and ventral view of digestive tract

wards, almost vertically; lips rather thick; the upper and lower jaw teeth both molar in form, each constitutes a set of half-moon tooth-bands. Mouth cavity large; small pointed teeth on the vomer and palatines. Tongue a rather large hemisphere, not entirely free, the surface being covered with a rather thick piece of mucous membrane with finger-print-like folds. A set each of front and back pharyngeal teeth on the upper pharyngeal bone and a set of bands on the lower, the teeth being small and sharp. No gill-rakers.

Peritoneal cavity rather large; peritoneum lacking in melanin chromatophores. Oesophagus short, wide, wall thick, mucous membrane 16 longitudinal folds. Stomach large, U-shape, about 45° aslant to the central axis of the body, wall thick, mucous membrane longitudinal serpentine folds with deep grooves, separated from the oesophagus by a valve. Duodenum thick, the pyloric part of the stomach being thinner. For instance, if the latter may be taken for the faucet, the former is the rubber tube which is fitted to the faucet. Intestine rather long (about thrice d~a), bends several times, wall thick, mucous membrane 13 to 14 zigzag longitudinal folds. Middle intestine separated from the rectum by a valve. Mesentery well developed. No pyloric appendage.

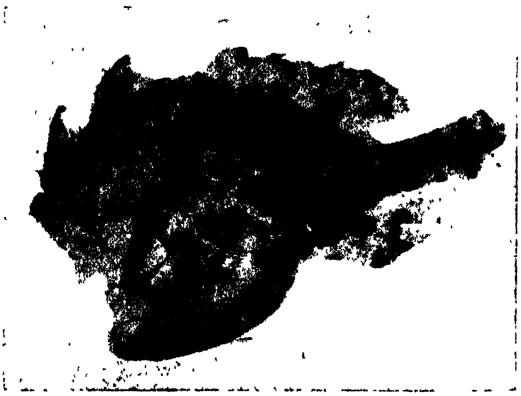


Fig. 189. *Pterophryne histrio* swallowing the fish larger than itself.

Liver rather large, thick, 2 lobes; gall-bladder large and spherical, located on the upper right of the cardiac part of the stomach; bile duct long, opening to the duodenum. Air-bladder large.

B. Feeding Habits.

Under normal conditions, this fish has its habitat among floating weeds and attacks fishes which gather there (this fish has a protecting colour). Although a very greedy sort (see the picture demonstrating the young of this fish about 1.5 cm long devouring a fish about its own size), it does not go in pursuit of its foods but waits for it, which means, as may be seen from the table, that it cannot always eat when it wants to eat.

Table 41

Stomach contents of *Pterophryne histrio*

Date	Locality	Number of fish	Av. body length (cm)	Stomach contents
Aug. 4, 1931	Mito, Sizuoka Pref.	15	14.5	Various young fishes (*Seriola*, etc.)..8/15, none....7/15
June 26, 1937	Aburatubo, Misaki	17	1.8	Various young fishes....10/17, none....7/17

150. *Antennarius tridens* (Temminck et Schlegel): Izariuwo.

A. Digestive System.

The body is almost the same as the foregoing species, the difference being the colour, the roughness of the body, and the fact that it has an antenna right above the mouth. Teeth-bands, tongue, pharyngeal teeth, are almost the same; gill-rakers also absent. The form of the alimentary canal is also almost the same, only the valve between the oesophagus and the stomach is not quite so distinct as the foregoing species. The duodenum is also thick, there being no material difference in the winding of the intestine. The liver is slightly larger but the air-bladder is trifly smaller. Cuvier and Valenciennes gives a description of the digestive organs of *Antennarius marmoratus* in their well known "Histoire naturelle de poissons", Vol. 12, p. 403, but there is not a great deal of difference between their description and that of the present species.

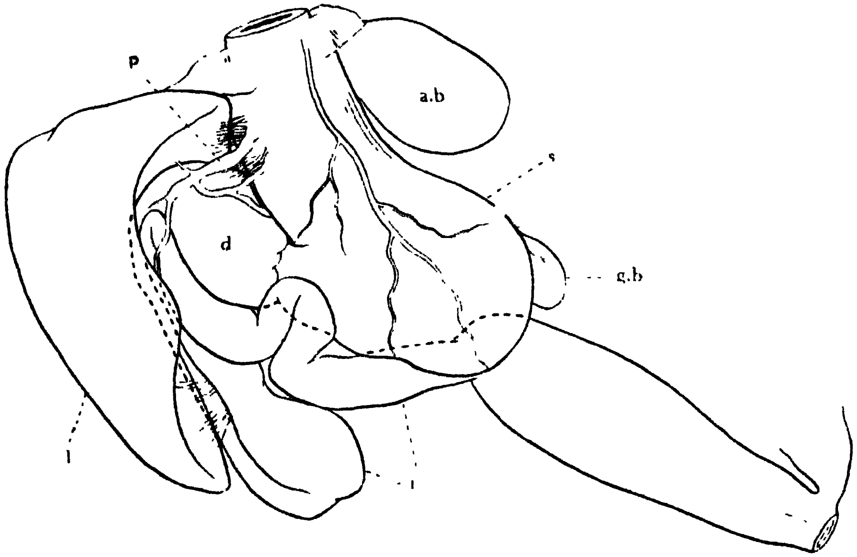


Fig. 190. *Antennarius tridens.*

B. Feeding Habits.

Contrary to the above species, this fish lives principally at the muddy bottom of shallow seas. In the summer of 1932, I put 5 of this fish caught near the Misaki Marine Biological Station with a dredge-net in an aquarium and watched them. They usually stayed at the bottom of the aquarium and when a small fish or a fish half-dead came within reaching distance of their mouth, they pounced upon it with a rather quick movement.

Discussion

I have now completed the description of the digestive system and feeding habits of 150 species of teleosts (mostly adults). Up to the present time many scholars have endeavoured to explain the relationship between the form and construction of their digestive organs and their feeding habits, and get fine results, yet there remains much to be solved, because they examined mostly each organ separately, for instance, the teeth, the gill-rakers, the stomach, or the intestine, taking not much into consideration the relationship of each organ or organs as a whole. It is quite necessary in order to know the true nature of the feeding habits of the fish that we should study the digestive organs not separately but also as a whole, always taking the constituents of the intestinal contents and the habitat of the fish in mind. During the present study, my attention has been paid to those points above mentioned.

I do not by any means think that my work is complete, yet I believe that the method which I have followed has made it possible to explain something which hitherto could not be explained, thus, making it possible to obtain a clearer understanding of the feeding habits.

DIGESTIVE SYSTEM

1. Form of Body.

The form of any fish has a very close connection with its movements, the moving power restricting its ability to catch food.

For example, fishes like *Scomber japonicus*, *Katsuwonus vagans*, Thunnidae, *Makaira mitsukurii*, *Xiphias gladius*, *Seriola quinqueradiata*, etc., whose form of body presents a perfect spindle, are the most skilful swimmers and can swim to the farthest places very quickly. They, therefore, go in pursuit of sardines and anchovies which are found in almost all parts of the sea in schools and migrate from place to place. And when they once come upon them, they try to eat as much as they can, taking advantage of their swift swimming power to swallow their food whole. That is to say, they make use of their swimming power to take as much food as they possibly can within a very short time. For this reason, their teeth have degenerated and instead they have a ᒣ-shape stomach with a large blind sac that can stand distension.

Etrumeus micropus, *Decapterus muroadsi*, *Sillago sihama*, and many other of its kind, also have spindle-form bodies but not as perfect as those given above; Tetraodontidae, Sparidae, *Leiognathus nuchalis*, *Zeus japonicus* and many others, have the oval or compressed oval form; *Cololabis saira*, *Hemirhamphus sajori*, Blenniidae, *Trichiurus haumela* and others or its kind have very elongated bodies. The less of spindle-form they are the lower in their swimming power, and, as a result, it so becomes that they have to look for food where so much energy and work are not required, for instance, they living along the coast or near the bottom. But in these instances, insofar as their life is concerned, the form of body limits only their living place and has very little to do with their feeding habits. However, when the form of body is no longer advantageous from the swimming point of view, their ability of getting food also becomes limited. For instances, fishes with depressed bodies, owing to their poor swimming ability, live near the bottom and feed on bottom food. Platycephalidae is a good example of this. *Parasilurus asotus* and Triglidae have rather similar body forms and, as a result, feed on bottom animals. Lophiidae, whose body is depressed in the extreme, rests quietly at the sea-bottom and moves the lures around its mouth to attract the fishes that are to be its food.

Of the fishes having compressed bodies, those with extremely compressed ones have poor swimming capacity and they are therefore cannot get creatures that are quick in action for their food. And so it is natural that *Mola mola* and *Stromateoides argenteus* take jelly-fish for their daily food, and also that Pleuronectidae lies on its side at the sea-bottom and feeds on shell-fishes in the sand and crabs which do not, more or less, move about so much. Anguillidae, Congridae, Muraenesocidae and Muraenidae with snake-like bodies are also slow in their movements, and they hide in caves and behind rocks and wait for their food. The very grotesque looking *Antennarius tridens* creeps along the bottom and takes mainly the dead animals. *Pterophryne histrio*, whose form is similar to *Antennarius tridens*, has a body similar to the colour of sea-weeds and is usually found among them, eating the small fishes and crustaceans that gather around the place. Further, those that are entirely unfit for swimming, as *Hippocampus coronatus*, entwine their tails around the branches of sea-weeds and use their tubular snouts as pipettes to take the minute food in the water. Echeneidae, whose dorsal fins have been transformed into suckers, attach themselves to the body of sharks and sword-fishes and, as everyone knows, take the food that has been left over by them. It is rather interesting to note that the bodies of these fishes having peculiar habit take the form of a spindle and, for a certain short length of time, they can swim with quite a speed, so that even when they become detached from the bodies of their hosts which have a forcible swimming power, they may go back to them again.

2. Mouth and Jaw.

The mouth and jaw have a very close connection with feeding habits. The size of mouth limits the food and the form of jaws controls the feeding habits to a certain extent.

a. Large mouth.

Engraulidae, *Saurida undosquamis*, *Dasiscopelus spinosus*, Siluridae, *Muraenesox cinereus*, *Gymnothorax kidako*, *Athlennes anastomella*, *Zeus japonicus*, *Trichiurus haumela*, *Makaira mitsukurii*, *Xiphias gladius*, Apogonidae, *Pseudoblennius*, *Chasmichthys*, *Otophidium asiro*, Lophiidae, and Antennariidae all have a mouth cleft and a mouth breadth of over 1/3 of head length, and the following come next: Plecoglossidae, Thunnidae, Coryphaenidae, and Pleuronectidae, etc. Among those listed above Siluridae, *Pseudoblennius*, *Chasmichthys*, Lophiidae, and Antennariidae have specially large mouth breadth.

It is interesting to note that as these fishes with large mouths are able to take large-size food, they are generally confirmed carnivores. It must also be mentioned that Engraulidae has a very large mouth, perhaps due to the necessity of its having to take in a large quantity of water with the plankton, and the Apogonidae that incubates their own eggs in its mouth. There are also many deep-sea fishes with large mouths, although I did not actually make the investigation myself, such as *Eurypharynx*, *Saccopharynx*, and many others.

b. Small mouth.

Fistularia petimba, *Syngnathus schlegeli*, *Hippocampus coronatus*, *Monocentris japonicus*, *Stromateoides argenteus*, Sillaginidae, *Chaetodon modestus*, *Siganus fuscescens*, and Plectognathi, have a mouth cleft or a mouth breadth of under 1/9 of head length, particularly those that belong to Plectognathi have small mouths. As these fishes with small mouths can only take small size food, it is impossible for them to be fierce carnivorous fishes. Not being carnivorous in their feeding habits, it is necessary for them to be in constant pursuit of food, regardless of what it may be, in order to get enough food. Plectognathi is a good example. It is however able to tackle rather large size food by tearing it to pieces little by little with its developed incisor-like teeth.

c. Direction of mouth.

Generally the mouth cleft turns upwards slightly in an oblique manner. However, there are some mouth clefts which turn upwards almost vertically. *Harengula zunasi*, *Brama raii*, *Arctoscopus japonicus*, *Inimicus japonicus*, Echeneidae, Uranoscopidae, Lophiidae and Antennariidae, are good examples. It is also worthy of note that the majority of fishes that rest quietly at the sea-bottom and wait for what food that comes from above belong to this group.

On the contrary, Dorosomatidae, Cobitidae and Triglidae, belong to the group where the mouth is located right under the anterior part of the body or in a definitely more inferior position. They are bottom feeders. Triglidae, for instance, lies at the bottom of the sea and feeds merely on bottom food.

d. Form of jaw.

The majority of fish have jaws of the ordinary length, the lower jaw being, in most cases, slightly longer than the upper. Some, however, have long both upper and lower jaws, while some others have an extremely long upper jaw compared to the lower or vice versa, as are shown in the following table.

Table 42

Upper and lower jaws extremely long	*Nemichthys*, Belonidae.
Upper jaw only extremely long	*Makaira mitsukurii*, *Xiphias gladius*.
Lower jaw only extremely long	Hemirhamphidae.
Cylindrical snout	Fistulariidae, Syngnathidae.

The stretched jaws of *Nemichthys* and Hemirhamphidae seem to work rather to a disadvantage from the feeding point of view, but in the Belonidae, they make use of their long jaws and the sharp teeth closely set within to take firm hold of its prey. *Makaira mitsukurii* and *Xiphias gladius* use their long, sharp upper jaw to kill large size animals, while Fistulariidae and Syngnathidae use their cylindrical snouts as pipettes to take in minute creatures into their mouths.

I have not as yet been able to make a study of what connection the long curved snout of *Gnathonemus* has with its feeding habits and the spatular jaw of *Polyodon*.

e. Protrusile mouth.

I have already described that the maxillary bone of *Leiognathus nuchalis* can be moved back and forth, and by this action, the protruded upper jaw may be used to advantage to take the food in the mud at the sea bottom. It is interesting to note that Sciaenidae, Sillaginidae, and others that hunt for food at the bottom have more or less similar mouths.

f. Bilateral asymmetry of mouth cleft.

The reason for the mouth cleft on the side without eyes of those fish belonging to the sub-family Pleuronectinae and family Cynoglossidae being larger than the side with eyes with the fact at the same time that the teeth on the side without eyes are also more developed is, I believe, due to their taking food with the side without eyes facing to the bottom. This is one of interesting examples of feeding adaptation.

3. Lip.

Generally, the lips of fishes are poorly developed, but there are some with thick fleshy lips.

Plecoglossus altivelis has thick lips, the tip portion of upper lip hanging vertically down and the lower turning vertically up, which, in my opinion, are used to advantage in licking off the blue-green and diatoms on rocks in the river. Triacanthidae, Balistidae, Monacanthidae, Ostraciidae, and Tetraodontidae also have thick fleshy lips. Hiyama (1934) says that there exist the mucous glands on the lips of those belonging to Monacanthidae, and it is not difficult to imagine that the lips of these fishes play an important part in collecting their food when they are tearing it off from rocks with their incisor-like teeth. It is also to be mentioned that those that search for food at muddy bottom generally have thick lips. Cobitidae, *Goniistius zonatus* are good examples.

4. Barbel.

There are a number of species that have barbels around their mouths; *Parasilurus asotus*, *Plotosus anguillaris*, *Carassius auratus*, *Cyprinus carpio*, *Misgurnus anguillicaudatus*, *Cobitis biwae*, *Upeneus bensasi*, *Podothecus acipenserinus*, *Otophidium asiro*, *Gadus macrocephalus*, *Theragra chalcogramma*, *Eleginus navaga* and *Lotella phycis* all come under this group and they are generally those that feed on bottom food.

According to Satô's (1936) study on the barbels of teleosts, there is an abundant distribution of cutaneous taste buds on the epidermis and they in turn have a good distribution of nerves, and they serve to taste food. I believe that it goes without saying that they play an important rôle when taking food.

5. Dentition (Pl. I).

a. No teeth.

Generally all fishes have some teeth, large or small in the jaws, on the pharyngeal bones, the vomer, the palatines, or the tongue, but a few of them have no teeth whatsoever. Of those which I have examined, Syngnathidae is a typical one without any teeth. Those belonging to the families Dorosomatidae, Dussmieriidae, Clupeidae, Engraulidae, Trachypteridae, have only rudimentary teeth. Naturally these fishes take minute food, such as the plankton, and cannot take anything wild and fierce, and what is interesting is that Thunnidae, Istiophoridae, Xiphiidae and *Seriola* all with a great swimming power and having the habit to take in a large quantity of food within a short time, have very poorly developed teeth, that is, those that do not require the teeth for mastication.

b. Developed jaw teeth (including those on vomer and palatines).

α) Teeth for seizing fishes quick in action. — Sharp canine teeth or tricuspid or hooked teeth.

Muraenesox cinereus (tricuspid teeth on mandible and vomer); *Gymnothorax kidako* (well developed teeth on jaws and vomer); *Athlennes anastomella* (large conical teeth in its long jaws); *Sphyraena pinguis* (in its jaws, on vomer and palatines); *Sawara niphonia* (in its jaws only); *Trichiurus haumela* (jaw teeth only, sharp and hooked, like fishing-hooks); *Scombrops boops* (in jaws only); Lophiidae.

β) Teeth for biting off food from rocks or tearing large size food slow in its movements. — Incisor-like teeth or canine teeth.

Oplegnathidae (jaw teeth polyphyodont); Labridae (canine-like jaw teeth); *Leptoscarus japonicus* (jaw teeth arranged in series of oblique rows); Triacanthidae, Balistidae, Monacanthidae, Tetraodontidae, Mollidae (incisor-like teeth); Ostraciidae (canine-like jaw teeth).

γ) Teeth for grinding shell-fishes and other hard food. — Molar teeth.

Pagrosomus major, *Taius tumifrons*, *Sparus swinhonis* (in the jaws only; mostly molar teeth, with large canine- or incisor-like teeth).

δ) Teeth for licking diatoms and blue algae off stones and rocks in rivers. — Comb-like teeth.

Plecoglossus altivelis.

Those having no large teeth as those described above have small or minute teeth, arranged in rows (*Saurida undosquamis*, etc.) or in bands (*Lateolabrax japonicus*, etc.), with which to seize their food. In the majority of these cases, it is worthy of note that the teeth grow more or less inward, facing the throat, so as to prevent the food from falling out when once it has been taken. (For example: Echeneidae, Lophiidae, etc.). The fact that there are larger and more teeth on the side without eyes than with eyes, as in the case of Pleuronectidae, is also an interesting adaptation to their feeding habits.

Sex-dismorphism may be in some Salmonidae, that is, the form of jaw teeth of the matured male and female differs from one another. The cylindrical jaw teeth of *Plotosus anguillaris* are worth mentioning.

c. Attachment of teeth.

In my present work, I do not attach so much importance to this subject, but I shall relate somewhat regarding the matter.

The teeth of many fishes are anchylosed, but there are some which are hinged.

a) Anchylosed teeth.

Most fishes have anchylosed teeth. The sharp teeth of *Trichiurus haumela* are good examples of this.

b) Hinged teeth.

Most of the jaw teeth of *Anguilla japonica, Epinephelus septemfasciatus*, Gadidae, Lophiidae, and the row of teeth on the vomer of *Gymnothorax kidako* are hinged teeth, and when they open their mouths, they stand up vertically to hold the food and when they shut their mouths, they bend inward toward the throat and help usher the food inside.

d. Developed pharyngeal teeth (Pl. II).

Parasilurus asotus (upper pharyngeal teeth developed); *Plotosus anguillaris* (cylindrical teeth); Cyprinidae (pharyngeal teeth specially well developed; important taxonomically); *Cypsilurus agoo* (tricuspid teeth); *Hapalogenys mucronatus* and *Ditrema temmincki* (lower pharyngeal teeth developed); Labridae (molar-like teeth); *Leptoscarus japonicus* (upper and lower both well developed, tessellated); *Mola mola*, Blennidae, etc. (upper pharyngeal teeth developed, long and sharp).

As already stated, jaw teeth serve to seize and hold food but pharyngeal teeth serve to grind food, and even in cases where there are not as developed pharyngeal teeth as those mentioned above, there are small or minute teeth closely set for grinding food. Very few of them are entirely without pharyngeal teeth. It is to be noted however that there are more instances where they are without the pharyngeal teeth than the jaw teeth. For example, Cyprinidae is about the only species with developed pharyngeal teeth but without any jaw teeth, while there are many with developed jaw teeth but no pharyngeal teeth, such as the majority of Apodes, Monacanthidae, Ostraciidae, Tetraodontidae, and a few others.

e. Relationship between jaw teeth and pharyngeal teeth.

Regarding the connection between the jaw teeth and the pharyngeal teeth, Ridewood (1896) states that the development of the pharyngeal teeth and the jaw teeth is inversely proportional to one another. This is about correct, however, as already stated, there are fishes without any jaw or pharyngeal teeth or with only rudimentary teeth, varying according to their food and feeding habits. Labridae and *Leptoscarus japonicus* both have developed jaw and pharyngeal teeth.

6. Tongue (Pl. III).

Of the tongues of various animals, the tongue of the fish is the most primitive of its kind, incapable of elasticity. It is merely an elevated area, consisting of glossohyal and the mucous membrane wrapping it.

a. Degenerated tongue.

The vast majority of fishes all possess a tongue large or small, but a few of them have no or degenerated tongue. *Dasiscopelus spinosus*, Syngnathidae, Trachypteridae (rudimentary).

b. Form of tongue.

The tongue (the surface) may be classified into 4 kinds of form, the triangular, the trianguloid, the semi-elliptic (including the semi-circular), and the rectangular, and in a few instances, there are special form.

α) Triangular.

Clupanodon punctatus, *Coilia mystus*, *Hypomesus olidus*, *Saurida undosquamis*, *Aplocheilus latipes*, Cyprinidae, Cobitidae, *Muraenesox cinereus*, *Gymnothorax kidako*, *Zeus japonicus*, *Beryx splendens*, *Scomber japonicus*, *Trichiurus haumela*, Carangidae, *Acanthocepola krusensterni*, *Branchiostegus japonicus*, *Lateolabrax japonicus*, *Sillago sihama*, Sparidae, *Hapalogenys mucronatus*, *Therapon oxyrhynchus*, *Ditrema temmincki*, *Chaetodon modestus*, Hexagrammidae, Cottidae, *Ammodytes personatus*, Blenniidae, *Otophidium asiro*, *Paralichthys olivaceus*, Pleuronectidae.

β) Trianguloid.

Etrumeus micropus, *Clupea pallasii*, *Harengula zunasi*, *Engraulis japonicus*, *Plecoglossus altivelis*, *Arctoscopus japonicus*, Apogonidae, *Sillago japonica*.

γ) Semi-elliptic.

Salmonidae, Siluridae, Anguillidae, Atherinidae, *Monocentris japonicus*, Thunnidae, *Sawara niphonia*, *Makaira mitsukurii*, *Xiphias gladius*, *Coryphaena hippurus*, *Brama raii*, Oplegnathidae, *Upeneus bensasi*, *Bryttosus kawamebari*, *Epinephelus septemfasciatus*, *Girella punctata*, Labridae, *Leptoscarus japonicus*, Plectognathi, Scorpaenidae, *Podothecus acipenserinus*, *Echeneis brachyptera*, *Uranoscopus japonicus*, Gadidae, Lophiidae.

δ) Rectangular.

Sardinia melanosticta, *Oncorhynchus keta*, *Salangichthys microdon*, Exocoetidae, *Cololabis saira*, *Sphyraena pinguis*, *Mugil cephalus*, *Katsuwonus vagans*, *Psenopsis anomala*, *Stromateoides argenteus*, *Leiognathus nuchalis*, *Scombrops boops*, *Stereolepis ischinagi*, *Siganus fuscescens*, Gobiidae.

ε) Special forms.

Those with long jaws, such as *Nemichthys scolopaceus*, *Fistularia petimba*, *Athlennes anastomella* and *Hemirhamphus sajori*, generally have a long tongue. However, *Makaira mitsukurii* and *Xiphias gladius* have long jaws and yet the tongue is of the ordinary length. The tongue of *Plecoglossus altivelis* is very small, trianguloid in form, on the sides of which are lips characteristically formed. The tongue of *Stromateoides argenteus* is rimmed on both sides. The tongue of *Spratelloides japonicus*, Congridae takes the form of a racket, while the tongue of *Sparus swinhonis* is shaped in the form of a pyramid and Platycephalidae a square fan.

c. Hardness.

The tongue is generally pretty hard, but the tongues of *Zeus japonicus*, *Monocentris japonicus*, Plectognathi, Pleuronectidae and Antennariidae are rather soft.

d. Movability.

The tongues of most fishes are free anteriorly, and by Musculi hypobranchiales, the anterior part being movable up and down, but some of them have the tongue which are not free. *Cyprinidae*, *Athlennes anatomella*, *Makaira mitsukurii*, *Xiphias gladius*, *Mugil cephalus*, *Upeneus bensasi*, *Girrella punctata*, *Mola mola*, *Periophthalmus cantonensis* and *Boleophthalmus pectinirostris* have such tongues.

e. Colour.

In the most cases the tongue is white, but there are not a few instances in which the surface is distributed with some melanin chromatophores, the quantity varying quite a great deal individually. When there is a very abundant distribution of melanin chromatophores it is black, which does not occur very often. The tongue of *Brama raii*, *Periophthalmus cantonensis*, *Rhinoplagusia japonica*, are really black. The tongue of *Sardinia melanosticta*, Scombridae and Katsuwonidae (the last two being silvery as well as black), are also black but in no way comparable with the former group. *Beryx splendens* and *Nibea mitsukurii* have red or orange tongue.

f. Tongue with teeth.

There are quite a fēw that have villiform or rather large sharp teeth on the surface of the tongue. For instance, some species of Salmonidae, Osmeridae, *Saurida undosquamis*, *Coryphaena hippurus*, some species of Carangidae, *Scombrops boops* and Echeneidae. Quite a number have rudimentary teeth, some species of Clupeidae being representative example.

It is not yet clear what the tongue actually has to do in taking food, but taking the Musculi hypobranchiales and the teeth on its surface into consideration, I should say that when the food is being ushered towards the throat, it more or less holds the food or helps it along. Herrick (1904) and a few others said that some fishes had taste buds that were distributed with cranial nerves. So it is probable that tongues of such fishes are used for tasting food as in the cases of barbels.

7. Gill-rakers (Pl. IV).

a. No gill-rakers.

Anguillidae, Congridae, Muraenesocidae, *Nemichthys scolopaceus*, Muraenidae, Fistulariidae, Syngnathidae, Belonidae, Sphyraenidae, *Makaira mitsukurii*, *Xiphias gladius*, Ostraciidae, Uranoscopidae, Cynoglossidae, Lophiidae, Antennariidae.

b. Rudimentary gill-rakers.

Gnathopogon caerulescens, *Sarcocheilichthys variegatus*, Cobitidae, Triacanthidae, Balistidae, Tetraodontidae, *Mola mola*, Hexagrammidae, Gobiidae, Blennidae, Pleuronectinae.

c. Extremely long gill-rakers.

Clupeidae, *Cololabis saira*, Atherinidae, Scombridae, Katsuwonidae.

d. Transformed gill-rakers.

α) Bunches of setae have taken the place of gill-rakers.

Saurida undosquamis, *Zeus japonicus*, *Sebastiscus marmoratus*, *Inimicus japonicus*, *Pseudoblennius*, *Dinogunellus grigorjewi*.

β) Forked gill-rakers.

Siganus fuscescens, *Enedrias nebulosus*.

γ) A bunch of setae between each forked gill-raker.

Trichiurus haumela.

e. Number.

Clupanodon punctatus — over 500; *Sardinia melanosticta* — about 140; *Mugil cephalus* — about 140; *Carassius auratus* — about 100; *Clupea pallasii* — about 72; *Cololabis saira* — about 50; *Katsuwonus vagans* — about 50; *Scomber japonicus* — about 40; *Lotella phycis* — about 10; *Bryttosus kawamebari* — about 7. There are also gill-rakers that exist only rudimentarily or none whatever, but I have already mentioned them. Thus, gill-rakers that are large in number are always long and closely set while those few in number are always short and coarsely arranged. This is true also vice versa.

f. Thickness of gill-rakers and feeding habits.

Hitherto it has been believed that the thickness of gill-rakers is to be seen in plankton feeders (including the bottom diatoms), that is, fish with gill-rakers closely set together are plankton feeders and those with coarsely arranged gill-rakers are not. Zander (1903, 1906) was an advocate of this observation. According to my investigation, it is true that those with thick gill-rakers are generally plankton feeders, but it cannot be said that those with coarse gill-rakers are not, since Fistulariidae, Syngnathidae and *Boleophthalmus pectinirostris* have totally degenerated gill-rakers, yet their chief food is the plankton or bottom diatoms.

g. Soft gill-rakers.

Generally the gill-rakers are stiff and flexible, but those of Plectognathi and *Boleophthalmus pectinirostris* are soft, especially so in the latter, and those of *Mola mola* are soft and fleshy.

h. Processes.

In most cases, there are more or less processes along each gill-raker. From Nakai's (1938) study of the processes of Clupeidae and a few others, it would seem that they play an important rôle at the time when the gill-rakers sieve and collect the plankton.

8. Peritoneal Cavity.

a. Specially large ones.

Aplocheilus latipes, Siluridae, *Zeus japonicus*, *Monocentris japonicus*, *Girella punctata*, *Ditrema temmincki*, *Leptoscarus japonicus*, *Siganus fuscescens*, Balistidae, Ostraciidae, Gadidae, Lophiidae, Antennariidae.

It is interesting to note that the majority of these fishes not only have a very poor swimming capacity but also they either have a large stomach or a long intestine, and some of them always keep quite a bit of food stored in their digestive organs. It is also worth noting that the viviparous *Ditrema temmincki* is among this group.

b. Specially small ones.

The peritoneal cavity of *Nemichthys scolopaceus* is representatively small in comparison with its body. It has a very long body but the cavity is extremely short and small. Trachypteridae and *Acanthocepola krusensterni* are similar to the above example. The body of Gobiidae is of ordinary size but the peritoneal cavity is very small.

c. Elongated ones.

Syngnathus, *Hemirhamphus sajori*, *Cololabis saira*, Apodes, *Sawara niphonia*, Ammodytidae, Blenniidae all have elongated bodies and their peritoneal cavities are likewise elongate.

d. Compressed ones.

Those with compressed bodies all have, almost without exception compressed cavities.

Harengula zunasi, *Coilia*, Trachypteridae, *Zeus japonicus*, *Coryphaena hippurus*, *Brama raii*, *Stromateoides argenteus*, *Alectis ciliaris*, *Leiognathus nuchalis*, Chaetodontidae, Triacanthidae, Monacanthidae, *Mola mola*, Pleuronectidae.

There are some with compressed peritoneal cavities with long intestines. The intestinal winding of these is, almost without exception, of the vortex type.

e. Depressed ones.

Those with depressed bodies generally have depressed peritoneal cavities. Platycephalidae and Lophiidae are good examples.

f. Vertically elongated ones.

Hippocampus is an example of the category.

The size and form of the peritoneal cavity do not directly affect the feeding habits of fish, but as the stomach, intestine, liver, etc. which are deposited in this cavity and have a close connection with its feeding habits, it cannot be said it has no connection whatsoever with the feeding habits.

9. Peritoneum.

Generally the peritoneum is a thin piece of membrane.

a. No melanin chromatophores.

In Congridae, Oplegnathidae, Branchiostegidae, Apogonidae, Serranidae, Plectognathi and others no melanin is found in the peritoneum. When no melanin chromatophores appear on the peritoneum, it is often silvery.

b. Black peritoneum.

Clupanodon punctatus, *Harengula zunasi*, *Engraulis japonicus*, *Plecoglossus altivelis*, *Hypomesus olidus*, *Dasiscopelus latipes*, *Carassius auratus*, *Hemirhamphus sajori*, Atherinidae, *Beryx splendens*, *Trachurus japonicus*, *Decapterus muroadsi*, *Upeneus bensasi*, *Girella punctata*, *Hapalogenys mucronatus*, *Thera-*

pon oxyrhynchus, *Boleophthalmus pectinirostris*, *Periophthalmus cantonensis*, *Gadus macrocephalus*, *Lophiomus setigerus*.

Hitherto, it was sometimes thought that those with black peritoneums are herbivorous fishes, but I do not think that is correct, inasmuch as, taking those from the same family, one would have a black peritoneum but the other would not. For instance, in the case of *Lophius* and *Lophiomus* (both belonging to the family Lophiidae), in identyfying them, it is important to know whether the peritoneum is black or not.

10. Method of Drawing Digestive Organs.

If you will look at the books and reports written up to the present time, you will find that when making a drawing of the digestive organs of a fish, the oesophagus is shown always at the top and the rectum at the bottom. This, I believe, was because anatomy was primarily connected with human being, human being in standing posture, but for reasons that will be gradually understood later, I have endeavoured to show them in their natural position, that is, in their horizontal position. This is extremely important in discussing the relative position of each organ.

11. Oesophagus.

The oesophagus of the fish is never so long as the other vertebrates. It is usually short, with a thick wall. Those that have comparatively long oesophaguses are Apodes, Fistulariidae, and so forth. Siluridae, Katsuwonidae, Thunnidae, Coryphaenidae, *Seriola*, Branchiostegidae, *Scombrops boops*, Sciaenidae, Scorpaenidae and Lophiidae have extremely short and wide oesophagus, also with thick wall.

An important item, besides its shortness and the thickness of its wall, in discussing the oesophagus of fish, is the fact that the mucous memhrane consists of longitudinal parallel folds in almost all instances. The folds number from 6 to 50. There are of course some mucous membrane consisting of papillae arranged in longitudinal folds, as in the case of Clupeidae and Mugilidae and a few others. Longitudinal folds are, to all reason, logical in broadening the oesophagus when it has to swallow large size food.

12. Stomach (Pl. V~VII).

a. No stomach.

Plotosus anguillaris, Cyprinidae, Syngnathidae, Belonidae, Hemirhamphidae, Exocoetidae, Scombresocidae, Atherinidae, *Ditrema temmincki*, Labridae, Callyodontidae, and *Mola mola* have no stomachs, and among them, *Plotosus anguillaris*, Cyprinidae, Belonidae, Exocoetidae, *Ditrema temmincki*, Labridae Callyodontidae, and *Mola mola* have extremely well developed pharyngeal teeth. The rest of them, however, Syngnathidae, Scombresocidae, and Atherinidae having no pharyngeal teeth are plankton feeders and therefore do not have to grind their food. It may be said therefore that those without stomachs and take large size food have, almost without exception, extremely well developed pharyngeal teeth. It is interesting to note that the following examples illustrate this inference very forcibly: *Parasilurus asotus* and *Plotosus anguillaris* belong to the same family Siluridae. The former, with minute conical pharyngeal teeth, has a stomach but the latter, contrary to the above, has no stomach but instead well developed cylindrical pharyngeal teeth.

b. Specially large stomach.

Zeus japonicus, *Pseudoblennius*, *Gadus macrocephalus*, Lophiidae and Antennariidae. These fishes are all gluttonous fishes.

c. Specially small stomach.

I-shape stomachs, i. e., cylindrical straight stomachs, are small in volume. Those belonging to the family Salangidae are representative examples of having very small stomachs and those of the Oplegnathidae have small V-shape stomachs.

d. Forms of stomach.

Stomachs are classified into 5 catergories, e. i., I-shape, U-shape, V-shape, Y-shape and ┤-shape according to their form.

α) I-shape.

Straight, cylindrical stomachs:

Salangidae, *Parasilurus asotus*, Fistulariidae, Plectognathi. Naturally, the long stomachs curve a little and the short ones bulge in the middle.

β) U-shape.

Cylindrical stomachs which curve in U-shape:

Clupanodon punctatus, *Salvelinus leucomaenis pluvius*, *Hypomesus olidus*, *Aplocheilus latipes*, *Stromateoides argenteus*, Antennariidae.

γ) V-shape.

Oncorhynchus, *Plecoglossus altivelis*, *Monocentris japonicus*, Oplegnathidae, *Upeneus bensasi*, *Acanthocepola krusensterni*, Sparidae, *Hapalogenys mucronatus*, *Therapon oxyryhnchus*, *Siganus fuscescens*, Agonidae, Triglidae, ete.

δ) Y-shape.

The above 3 forms of stomach, α), β) and γ) have either no blind sacs or anything definite corresponding to it. There are often when it is difficult to distinguish the V-shape from the forms Y-shape stomachs. But the groups of fishes listed hereunder and the ones following all definitely have a blind sac:

Examples of distinct Y-shape stomachs: The majority of Clupeidae and Apodes, Myctophidae, etc., not very many.

ε) ┤-shape.

Saurida undosquamis, *Sphyraena pinguis*, *Beryx splendens*, Scombridae, Katsuwonidae, Thunnidae, *Sawara niphonia*, *Trichiurus haumela*, *Makaira mistsukurii*, *Xiphias gladius*, *Coryphaena hippurus*, *Brama raii*, Carangidae (especially *Seriola*), Branchiostegidae, some of Serranidae, Sciaenidae, Scorpaenidae, Ammodytidae, *Dinogunellus grigorjewi*, Gadidae, etc. Hippoglossinae have a curved one.

The ┤-shape stomach is generally conical in shape with a large blind sac and an extremely small pyloric part. This type of stomach is possessed by Scombroid fishes and a few others that take a large quantity of food at one time not obtaining food regularly.

ζ) Systematical relation of stomach.

In my opinion, the I-shape and U-shape stomachs are of the same type systematically, and V-shape, Y-shape and ˥-shape of another type: when considering the matter from the construction point of view, the U-shape stomach is only a transformation of the I-shape stomach, curving into the letter U, and the V-shape stomach is considered a kind of the Y-shape stomach which its blind sac has degenerated, and the ˥-shape stomach is only the transformation of the Y-shape, the cardiac part and the blind sac of which forming one straight line.

e. Fore-stomach.

In Stromateidae and Pampidae there is a black, oval fore-stomach, with a thick wall and a chitinized mucous membrane between the oesophagus and the ordinary stomach. It is quite clear what this organ is required for, and undoubtedly it helps to crush their chief food, the jelly-fish.

f. Wall of stomach.

The stomach wall is generally thick, particularly the wall of the ˥-shape stomach and the stomachs of voracious fishes. When much contents are contained in the stomach, the wall, of course, becomes stretched to a thinner degree. Of the different parts of the stomach, the wall of the pyloric part is the thickest. This part of *Clupanodon punctatus* and *Mugil cephalus* is developed in muscles and takes the form of a humming-top or a bird's gizzard. As their principal food is organic detritus with much diatom, perhaps it is an adaptation to the necessity of crushing and pressing the contents. *Sardinia melanosticta*, a diatom feeder, has similarly a well developed pyloric part of muscular wall and so has the *Siganus fuscescens* that feeds chiefly on sea-weeds.

g. Folds of mucous membrane (Pl. VI, VII).

The folds of the mucous membrane of the stomach are more varied than those of the oesophagus but not so much as the folds of the intestine. Generally, the folds of the cardiac part and the blind sac are similar or the same, or the folds of the pyloric part being slightly different. But there are some instances, as in the case of Clupeidae, Osmeridae and a few others, where the folds of the mucous membrane differ greatly with each part of the stomach. As shown in Pl. VI, Figs. 1~3, the folds of the cardiac part in the Y-shape stomach of *Sardinia melanosticta* (Clupeidae) are oblique bands, the blind sac longitudinal serpentine folds, and the pyloric part small papillae arranged in longitudinal rows; while those of the cardiac part of the U-shape stomach of *Hypomesus olidus* (Osmeridae) consist of papillary processes arranged in longitudinal rows, and the pyloric part of ordinary longitudinal folds.

As explained above, the folds of the mucous membrane differ somewhat according to each part of the stomach, but let us now turn our attention to the central part of the stomach, just between the cardiac part and the blind sac, and examine the folds of the mucous membrane for that part. It will be seen that they can be divided into 6 (α~ζ) types: —.

α) Longitudinal parallel folds.

Besides the typical longitudinal folds of ***Fistularia petimba*****,** ***Branchiostegus japonicus*****,** ***Etrumeus micropus*** and two or three other species of Clupeidae, *Dasiscopelus spinosus*, *Parasilurus asotus*, *Sphyraena pinguis*, *Beryx splendens*, *Sparus swinhonis*, Plectognathi, Platycephalidae, and so forth, may be included in this type. The folds number from about 5 to 40.

β) Longitudinal serpentine folds.

This is a common type. Beginning with the very simple folds of *Sillago sihama* and Congridae, *Makaira mitsukurii*, *Xiphias gladius*, Sciaenidae, *Girella punctata*, *Sebastodes matsubarae* and other Scorpaenidae, *Kareius bicoloratus* and other Pleuronectidae following, we pass on the complicated folds of *Trichiurus haumela* and Lophiidae, of which the folds of most fishes are made. There are also folds, such as those of *Misgurnus anguillicandatus*, *Cobitis biwae*, and others, which it is more appropriate to describe as zigzag folds than serpentine folds.

γ) Longitudinal folds with transversal folds.

There are some longitudinal parallel folds and longitudinal serpentine folds which connect each fold, that is, they have transversal folds, and they are often found near the tip of the blind sac. Look at the folds of *Anguilla japonica* and *Gadus macrocephalus*.

δ) Longitudinal folds with fine longitudinal folds between the folds.

Pagrosomus major and a few others.

ε) Longitudinal folds with net-work between the folds.

Clupea pallasii, *Oncorhynchus*, Hexagrammidae, etc.

ζ) Longitudinal folds with papillary processes between the folds.

Lepidotrigla microptera, etc.

It is an interesting fact that almost all stomachs have thick walls, especially the ┐-shape stomachs of gluttonous fishes, and the longitudinal arrangement of the folds of the mucous membrane, about which I have just finished describing is, I believe, an important factor in the functioning of the stomach. Because at the time of feeding when the stomach requires expansion, the longitudinal construction of the folds of the mucous membrane that must necessarily stretch with the muscles allows it to do so very capably.

h. Situation of the pyloric part of stomach.

The position of the pyloric part in relation to the stomach is interesting. From my examination of 150 species of teleosts all of them, without exception, had their pyloric part situated at the lower part of the stomach.

13. Intestine (Pl. VIII~XII).

There are various kinds of intestines as may be thought easily, —long and short—and as to their various types of winding, they are certainly variable and many fishes do not have a stomach but none is without an intestine.

a. Length of intestine.

When I say the length of the intestine, I mean the length measuring from the beginning of the intestine, i. e. the beginning of the duodenum to the end of the intestine, i. e. the anus. In indicating the length of the intestine, I have employed the method of dividing the intestine by the distance between the 2 points mentioned above, that is, the straight line between d~a.

Table 43

Length of intestine compared with d∼a	Species of fish
As long as d∼a or trifly longer	*Etrumeus micropus, Spratelloides japonicus, Clupea pallasii, Harengula zunasi, Coilia mystus, Oncorhynchus keta, Plecoglossus altivelis, Hypomesus olidus, Salangichthys microdon, Saurida undosquamis, Misgurnus anguillicaudatus, Cobitis biwae, Anguilla japonica, Nemichthys scolopaceus, Fistularia petimba, Syngnathus schlegeli, Athlennes anastomella, Hemirhamphus sajori, Cypsilurus agoo, C. japonicus, Cololabis saira, Trachypterus iris, Sphyraena pinguis, Katsuwonus vagans, Sawara niphonia, Echeneis brachyptera.*
Ca. 1.2 times	*Astroconger myriaster, Alloconger anagoides, Muraenesox cinereus, Gymnothorax kidako, Nibea mitsukurii, N. argentata.*
Ca. 1.3 times	*Harengula zunasi, Salvelinus leucomaenis pluvius, Dasiscopelus spinosus, Atherina bleekeri, Halichoeres poecilopterus, Pseudolabrus japonicus, Pterogobius elapoides, Enerdrias nebulosus.*
Ca. 1.4 times	*Atherina tsurugae, Bryttosus kawamebari, Sillago sihama, S. japonica, Ammodytes personatus.*
Ca. 1.5 times	*Sarcocheilichthys variegatus, Thunnus orientalis, Parathunnus sibi, Neothunnus macropterus, Lophius litulon.*
Ca. 1.6 times	*Gnathopogon caerulescens.*
Ca. 1.8 times	*Clupanodon punctatus.*
Ca. 2 to 2.2 times	*Sardinia melanosticta, Plotosus anguillaris, Tribolodon hakonensis, Makaira mitsukurii, Coryphaena hippurus, Brama raii, Upeneus bensasi, Acanthocepola krusensterni, Apogon semilineatus, Scombrops boops, Lateolabarx japonicus, Hapalogenys mucronatus, Pseudoblennius percoides, P. cottoides, P. marmoratus, Chasmichthys dolichognathus gulosus, C. d. dolichognathus.*
Ca. 2.3 to 2.5 times	*Hippocampus coronatus, Apogon lineatus, Goniistius zonatus, Triacanthus brevirostris, Monacanthus cirrhifer, Platycephalus indicus, Inegocia japonica, Periophthalmus cantonensis, Dinogunellus grigorjewi, Lepidopsetta mochigarei, Limanda yokohamae, Kareius bicoloratus, Gadus macrocephalus, Theragra chalcogramma*
Ca. 2.6 to 2.8 times	*Beryx splendens, Stereolepis ischinagi, Uranoscopus japonicus, Paralichthys olivaceus, Atheresthes evermanni, Hippoglossoides elassodon.*
Ca. 3 times	*Parasilurus asotus, Monocentris japonicus, Scomber japonicus, Xiphias gladius, Psenopsis anomala, Trachurus japonicus, Decapterus muroadsi, Seriola quinqueradiata, S. aureovittata, S. purpurascens, Branchiostegus japonicus, Pagrosomus major, Taius tumifrons, Sparus swinbonis, Therapon oxyrhynchus, Aracana aculeata, Spheroides rubripes, S. vermicularis,* Scorpaenidae, *Lepidotrigla microptera, Trypauchen vagina microcephalus, Otophidium asiro, Eleginus navaga, Pterophryne histrio, Antennarius tridens.*
Ca. 3.5 times	*Engraulis japonicus, Arctoscopus japonicus, Epinephelus septemfasciatus*
Ca. 4 times	*Cyprinus carpio, Ditrema temmincki, Lotella phycis.*
Ca. 4.5 times	*Hexagrammos otakii, Agrammus agrammus.*
Ca. 5 times	*Aplocheilus latipes.*
Ca. 5.5 times	*Leptoscarus japonicus.*
Ca. 6 times	*Leiognathus nuchalis, Oplegnathus fasciatus, Girella punctata, Boleophthalmus pectinirostris* (for this species only, the length is measured according to o∼a).
Ca. 7 times	*Chaetodon modestus.*
Ca. 8 times	*Siganus fuscescens, Mola mola.*
Ca. 9 times	*Stromateoides argenteus.*
Ca. 10 times or over	*Carassius auratus* (differs a great deal), *Mugil cephalus.*

b. Winding-type of intestine (Pl. VIII).

Let us take 2 fixed points d and a, and imagin the various lengths of intestines between those 2 points; if the length of the intestine is of equal length, from d to a, it will constitute a straight line; if it is longer, it will hang down and forming the letter U or V according to the length of the intestine. But as already explained, the body of the fish in general requires a great deal of muscles for swimming. Therefore, in most cases, the peritoneal cavity forms necessarily not a large space, in which a number of digestive organs and gonads must be deposited. It has therefore to find a means of arranging its long intestine, for which there is no other way but to wind itself in such a manner as best fitted for the purpose.

When the length of the intestine is equivalent to d~a, or a little longer, it naturally runs in a straight line or curves just a little bit (Pl. VIII, Fig. 1). But those that are ca. 1.2 times as long as d~a, present a notch, as in *Gymnothorax kidako*, or make a short turning as characteristically represented in Apodes and Sciaenidae; those ca. 1.3 times d~a, are seen in *Harengula zunasi* and others in the form of a S; in *Dasiscopelus* in the form of an r; in *Atherina bleekeri* and Labridae in a characteristic circular winding; and in *Enedrias nebulosus* in a very peculiar zigzag turning. Among those ca. 1.4 times d~a, a large number of them take the midway N-shape form, that is, the short turnings of the N-form (note the 2 turning points which lengthen in the direction on the arrows) are about to run into the long turnings, and those from ca. 1.5 to 3 times generally take the N-shape winding. The longer it is the more perfect the N winding is apt to be. Another interesting feature of the arrangement of the intestine is the vertical type of winding, the way of which is employed in arranging a long intestine in a compressed peritoneal cavity. The intestines of *Chaetodon modestus* and *Siganus fuscescens*, which I shall describe later, are typical examples [of long intestines, but even those that come under this group of the length from 1.5 to 3 times, take more or less this form of winding, such as the intestines of *Clupanodon punctatus*, *Sardinia melanosticta*, the majority of Plectognathi, and Pleuronectidae, etc., and if you will scrutinize the figures, you will see that this type of winding has been derived from the N-shape type of winding; this is a very important fact. Besides those described above, there are the horizontal zigzag windings of *Plotosus anguillaris* and *Sphaeroides rubripes*, the vertical zigzag winding (slightly inclined to coil) of *Xiphias gladius*, and the somewhat indeterminate types of *Hippocampus coronatus*, *Gadus macrocephalus*, *Parasilurus asotus*, *Branchiostegus japonicus*, Antennariidae, etc.

There are not many intestines over ca. 3.5 times of d~a. They cannot logically take the form of a typical N-shape. However, the intestines of *Arctoscopus japonicus* and *Epinephelus septemfasciatus* come near to this type but it is nevertheless quite transformed. Now let us compare and consider those over 3.5 times long. First the intestines of *Engraulis japonicus*, ca. 3.5 times and *Aplocheilus latipes*, ca. 5 times, have very rare and curious types of winding. These types, when first viewed, look like ordinary coiling but on further scrutiny, it will be seen that the former is a peculiar type derived from the N-shape and the latter from the zigzag winding. The intestine of *Oplegnathus*, ca. 6 times long, is a twisted N-shape winding, forming the letter 8, and the intestine of *Stromateoides argenteus*, ca. 9 times long, (note, however, that this species has 2 kinds of intestine: one that is very long and narrow and anothter one that is broader and trifly shorter), is a more complicated form of that same type of winding, in that it winds back and forth several times. The intestine of *Mola mola* (ca. 8 times) also winds in a type similar to this. The intestines of those with compressed peritoneal cavities, *Leiognathus nuchalis* (ca. 6 times), *Chaetodon modestus* (ca. 7 times), and *Siganus fuscecscens* (ca. 8 times), winds in the form of a vortex, the first and latter parts of which winding in opposite directions. The intestinal winding of *Girella punctata* (ca. 6 times) takes the form of a semi-circular plane of a vortex, and *Boleophthalmus pectinirostris*, ca. 6 times, a rough form of the letter N, plus a vortical winding in the central part. The long intestines of *Carassius auratus* and *Mugil cephalus*, over 10 times, are complicatedly arranged, winding back and forth, plus a combination of the torsional and vortical types of winding.

As may be gathered from the above, except for a few examples of the zigzag type of winding and two or three other types, it may be said that all intestines are of the N-shape type of winding, or types derived from this form, and this is an important matter which must be carefully noted.

I have on several occasions used the term "type of winding derived from the N-shape type", however, I used this phrase merely to describe the form. The intestines that are merely straight at the larval stage begin to form the letter N as they develop with the growth of the body, and that although those that are destined to have longer intestines take various other forms which characterize them, they are founded at first on this particular type of winding.

The intestinal type of winding of those belonging to the same genus is generally the same but this is not usually so in the case of families. There are, however, minor differences, i. e., individual variations, such as the length of the intestine and other minor details which do not affect the type of winding characterizing the intestine of that fish. These differences occur in the middle parts of the intestine.

c. Width of intestine.

α) Specially wide intestine.

With the exception of *Aplocheilus* and *Leptoscarus*, the rest fishes coming under this category have straight intestines: *Saurida undosquamis*, *Aplocheilus latipes*, Belonide, Hemirhamphidae, Exocoetidae, *Leptoscarus japonicus*, etc.

β) Specially narrow intestine.

Those with long intestines, such as *Carassius auratus* and *Mugil cephalus.*

γ) Intestine narrow when the stomach is large.

Zeus japonicus, *Trichiurus haumela*, *Pseudoblennius*, *Gadus macrocephalus*, Lophiidae, Antennariidae, etc., and many of those with intestines of this description are voracious carnivora.

d. Thickness of intestinal wall.

α) Specially thick.

Siluridae, *Anguilla japonica*, Exocoetidae, *Makaira mitsukurii*, *Xiphias gladius*, *Brama raii*, *Psenopsis anomala*, Serranidae, *Mola mola*. Platycephalidae, *Pterogobius elapoides*, Echeneidae, Blenniidae, Pleuronectidae, of these I should say the wall of Exocoetidae is the thickest.

β) Specially thin.

Aplocheilus latipes, Cobitidae, Trachypteridae, Atherinidae, Apogonidae, Triacanthidae, Balistidae, Monacanthidae, Ostraciidae, Cottidae. I should say that Cobitidae has the thinnest intestinal wall.

e. Folds of mucous membrane at the middle part of intestine (Pl. IX∼XII).

It should be noted that among the various folds of the mucous membrane of the digestive tract, the folds of the oesophagus are the simplest, the stomach next, and the intestine the most complicated. As there are various intestinal lengths, there naturally arises the question of absorbing the nutrition.

It is very difficult to classify all the different folds. At any rate, I have classified them (principally the folds of the mucous membrane of the middle part of intestine) in the following manner. I have to add that there are times, as in the case of the stomach, when the folds of the intestine are stretched or worn out on account of the contents inside and not in their normal condition. For instance, when there are large contents, the papillary process of the mucous membrane on a background of network becomes erase and only the net-work remains. In order to avoid making any mistakes, I examined as many as I could and also those in the aquarium almost in a state of fasting.

α) No fold.

Cobitidae.

β) Few folds.

Sciaenidae. *Gadus macrocephalus*, *Theragra chalcogramma*, *Eleginus navaga*.

γ) Longitudinal folds.

Syngnathus schlegeli, *Arctoscopus japonicus*, *Chaetodon modestus*, Lophiidae. The longitudinal folds of *Scomber japonicus* have vertical waved ridges, while the folds of Platycephalidae have warts between the longitudinal folds, and the folds of *Stromateoides argenteus*, etc. are inclined to be serpentine.

δ) Longitudinal zigzag folds.

The majority of Cyprinidae, and *Spratelloides japonicus*, *Trachypterus iris*, *Beryx splendens*, *Leiognathus nuchalis*, *Hapalogenys mucronatus*, *Ditrema temmincki*, Antennariidae, etc. The folds of *Ditrema* are the most typical of this kind. There are others like the papillary processes of *Scombrops boops* arranged in this zigzag form.

ε) Transversal folds.

Clupanodon punctatus, *Etrumeus micropus*, *Clupea pallasii*, *Sardinia melanosticta*, *Engraulis japonicus*, *Coilia mystus*, Salmonidae, Plecoglossidae, Osmeridae, Salangidae, and the folds of the intestine of those belonging to the group of Isospondyli are so arranged.

γ) Transveral zigzag folds.

These folds are not very clear, but they are seen in *Aplocheilus latipes*, *Monocentris japonicus*, etc., besides which the papillae of *Fistularia petimba* are arranged in this manner.

η) Net-work.

The folds of *Cyprinus carpio* are typical examples of single net-work. It is to be noted that while other Cyprinoid fishes have longitudinal zigzag folds, the carp alone has folds of a single net-work. *Gymnothorax kidako*, *Trichiurus haumela*, and *Stereolepsis ischinagi* are those with typical double net-work. The following have either single or double net-work folds: the lower part of the middle intestine of *Oncorhynchus*, *Anguilla japonica*, *Zeus japonicus*, *Makaira mitsukurii*, *Brama raii*, *Psenopsis anomala*, Serranidae, *Goniistius zonatus*, Scorpaenidae, Hexagrammidae, Cottidae, Agonidae, Trigridae, *Boleophthalmus pectinirostris*, Blenniidae, etc. The folds of Sparidae are combinations of net-work and papillae.

θ) Papillary process.

Congridae, *Muraenesox cinereus*, Belonidae, Hemirhamphidae, Exocoetidae, *Cololabis saira*, Sphyraenidae, *Mugil cephalus*, Atherinidae, Katsuwonidae, Thunnidae, *Xiphias gladius*, *Coryphaena hippurus*, Carangidae, Oplegnathidae, Branchiostegidae, Apogonidae, *Therapon oxyrhynchus*, *Siganus fuscescens*, Plectognathi, *Pterogobius* and other Gobiidae, Echeneidae, *Uranoscopus japonicus*, *Ammodytes personatus*, Cynoglossidae, etc. There are others: *Leptoscarus japonicus* that has extremely long papillary processes and Pleuronectidae with petaloid papillae. The Sparidae mentioned above might be included with this group.

ι) Branched folds.

Saurida undosquamis, *Upeneus bensasi*, *Periophthalmus cantonensis*, *Lotella phycis*, etc.

In a long intestine, the folds of the mucous membrane are not always the same in all parts but vary in some parts. This may be observed clearly in *Oncoryhynchus keta* and *Mugil cephalus*. The folds of a short intestine are generally complicated as in the instance of double net-work folds.

f. Rectum.

Almost all fishes have a rectum, but it cannot be distinguished clearly from outside, but on cutting the intestine open, is will be seen that in most cases, a valve divides the rectum and the middle intestine distinctly. There are some instances, however, in which the rectum is broader than the middle intestine and may be distinguished clearly from outside: Syngnathidae, *Inimicus japonicus*, *Pterogobius elapoides*, *Chasmichthys*, *Ammodytes personatus*, etc. are examples of this. The development of the folds of the mucous membrane of the rectum is generally poorer than those of the middle intestine.

g. On the length of intestine and feeding habits.

It has been considered up to the present time that aminals with long intestines are herbivorous in their feeding habits, and those that have short intestines are generally carnivorous. However, that is not always true, because not only are the vast majority of fishes omnivorous in their feeding habits but *Plecoglossus altivelis*, a feeder on blue-green algae and diatoms, has a very short intestine, and such fish as *Xiphias gladius*, a purely carnivorous fish, has a long intestine. But speaking generally, herbivorous fishes have long intestines (Examples: *Laptoscarus japonicus*, *Girella punctata*, *Boleophthalmus pectinirostris*, *Siganus fuscescens*, etc.).

14. Pyloric Appendage (Pl. XIII, XIV).

a. Number.

As listed above, the number of pyloric appendages ranges from zero to over a thousand. In some cases, all the species belonging to one particular family have the same number, but there are some others that differ materially with each species, although of the same family. This is clearly illustrated in Blenniidae, for some of its species have pyloric appendages and the others have none. Thus, it may be said that the greater the number of appendages, the greater their individual variation.

b. Length of pyloric appendage.

α) Long pyloric appendage.

The following fishes have long appendages.

Sphyraena pinguis, *Beryx splendens*, *Monocentris*, *japonicus*, *Scomber japonicus*, *Stromateoides argenteus*, *Trachurus japonicus*, *Decapterus muroadsi*, Hexagrammidae, *Lepidotrigla micropterus*, etc.

β) Short pyloric appendages.

The following fishes have short appendages.

Clupanodon punctatus, *Spratelloides japonicus*, *Engraulis japonicus*, *Plecoglossus altivelis*, *Hypomesus olidus*, Synodontidae, Trachypteridae, Zeidae, Branchiostegidae, *Girella punctata*, Sparidae, *Goniistius zonatus*, Uranoscopidae, Ammodytidae, Pleuronectidae, Lophiidae, etc.

γ) Irregular lengths.

The lengths of most pyloric appendages growing in clusters are bound to be more or less irregular, but the followings are outstanding examples: of the 5 pyloric appendages of *Brama raii*, 2 are long and broad while the other 3 are short and narrow; of the 5 of *Sillago sihama*, only 1 of them is long; of the 3 of *Siganus fuscesecens*, 2 are long and 1 is short, and there exist a few similar instances.

c. Some pyloric appendages requiring special mention (Pl. XIV).

Saurida undosquamis has about 20 pyloric appendages, but as they are so extremely short, they are apt to be overlooked; the pyloric appendages of Katsuwonidae, Thunnidae, Istiophoridae, Xiphiidae, Coryphaenidae, Echeneidae, form 1 compact mass by means of connective tissues and are often erroneously taken for the liver or the pancreas. The pyloric appendages of *Sawara niphonia* are also great in number but do not quite form a compact mass as in the above cases. They are similar to those of *Prochilodus insignis* described by Pernkopf (1930) in his book, and the appendages of *Psenopsis anomala* are similar to those of *Lepidosteus osseus* discovered also by Pernkopf.

d. Folds of mucous membrane.

Table 44

Number of pyloric appendage	Fish
None	Salangidae, Cyprinodontidae, Siluridae, Cyprinidae, Cobitidae, Anguillidae, Congridae, Muraenesocidae, Nemichthydae, Muraenidae, Fistulariidae, Syngnathidae, Belonidae, Hemirhamphidae, Exocoetidae, Scombresocidae, Atherinidae, Embiotocidae, Labridae, Callyodontidae, Triacanthidae, Balistidae, Monacanthidae, Ostraciidae, Tetraodontidae, *Mola mola*, Gobiidae, *Enedrias nebulosus*, Cynoglossidae, Antennariidae.
1	Ammodytidae (rudimentary)
2	*Mugil cephalus*, *Branchiostegus japonicus*, *Bryttosus kawamebari*, *Lophiomus setigerus*.
3	*Nibea argentata*, *Siganus fuscescens*.
4	Apogonidae, Sillaginidae, Sparidae, *Hapalogenys mucronatus*, *Goniistius zonatus*, most of Pleuronectidae.
5	*Hypomesus olidus* (sometimes 6), *Brama raii*, *Nibea mitsukurii*, *Dinogunellus grigorjewi*.
6	*Monocentris japonicus*, Platycephalidae, *Podothecus acipenserinus*.
7	*Arctoscopus japonicus*, *Acanthocepola krusensterni*.
8	*Lepidotrigla microptera*, *Uranoscopus japonicus*, *Limanda yokohamae* (8 to 14).
9	*Dasiscopelus spinosus*.
Usually 10	*Sebastodes inermis*, *Pseudoblennius*.
,, 11	*Upeneus bensasi* (11 to 14), *Otophidium asiro*.
,, 12	*Scombrops boops* (12 to 14), *Stereolepsis ischinagi*, *Therapon oxyrhynchus*.
,, 14	*Salvelinus leucomaensis pluvius*.
,, 15	*Spratelloides japonicus*, *Coilia mystus*, *Trachurus japonicus*.
,, 18	*Decapterus muroadsi* (18 to 24).
About 25	*Clupea pallasii* (25 to 27), *Engraulis japonicus*, *Sphyraena pinguis*.
,, 30	*Beryx splendens*, *Alectis ciliaris*.
36–39	*Harengula zunai*.
About 40	*Oncorhynchus masou* (40–45), *Seriola aureovittata*.
45–50	Hexagrammidae.
About 50	*Oplegnathus fasciatus*.
,, 60	*Seriola purpurascens*.
63–67	*Eleginus navaga*.
About 80	*Oncorhynchus nerka*.
,, 90	*Theragra chalcogramma*.
,, 120	*Sardinia melanosticta*.
120–150	*Zeus japonicus*.
About 150	*Oncorhynchus keta*, *Scomber japonicus*. *Girella punctata*.
150–160	*Epinephelus septemfasciatus*.
About 200	*Trachypterus iris*.
250–300	*Seriola quinqueradiata*
350–400	*Plecoglossus altivelis*.
About 380	*Gadus macrocephalus*.
Roughly 600	*Stromateoides argenteus*.
,, 1000	*Etrumeus micropus*.
Countless number	*Clupanodon punctatus*, Katsuwonidae, Thunnidae, Cybiidae, Istiophoridae, Xiphiidae, Coryphaenidae, Echeneidae.

The pyloric appendages of fishes were mistaken for the pancreas up to the end of the 19 century, but this was rectified by Legouis (1873) and Laguesse (1894). By pointing out the similarity of the folds of the mucous membrane of the pyloric appendages and the intestine, Jacobshagen (1911) proved that pyloric appendages were coecal outgrowths of the intestine. The writer also compared the folds of these both organs and found them practically the same

15. Colour of Digestive Tract.

The colour of the digestive tract, including the stomach, the intestine and the pyloric appendages, when fresh, is generally pale yellow (almost white or pink, but there are few with other colours. The intestines of sardines and anchovies are green when they have fed on diatoms and brown when they have fed on Copepods. Put out of the question they are only the colours of the intestinal contents showing through the wall.

Table 45

Family	Species	Colour	
		Stomach	Intestine
Engraulidae	*Engraulis japonicus*	greyish black	black
,,	*Coilia mystus*	pink	red
Myctophidae	*Dasiscopelus spinosus*	greyish black	black
Apogonidae	*Apogon lineatus*	black	,,
Cynoglossidae	*Rhinoplagusia japonica*	usual colour	usual colour
,,	*Areliscus joyneri*	greyish black	,,

16. Mesentery.

Mesentery is something that is not usually well developed in a fish, but some of it are quite thick, even with mesenteric roots (Radix mesenterii) existing distinctly. Examples of developed mesentery are: *Parasilurus asotus*, Thunnidae, *Makaira mitsukurii*, *Xiphias gladius*, *Coryphaena hippurus*, *Leiognathus nuchalis*, Sparidae, *Goniistius zonatus*, *Siganus fuscescens*, Plectognathi, Pleuronectidae, Lophiidae, Antennariidae, etc.

17. Liver.

Most fishes have an ordinary liver, but some have what is called a "hepatopancreas", that is, a combination of the liver and the pancreas. I have already written on the history and discoverer of this organ, but from my study of various materials, *Cyprinus carpio* is a representative example of that with a hepatopancreas, the others being *Plotosus anguillaris*, Syngnathidae *Therapon oxyrhynchus*, Sparidae, some Gobiidae, Pleuronectidae, etc.

a. Form.

The liver of most fishes usually consists of 2 lobes (bilobes), i. e. the left lobe (Lobus sinister) and the right lobe (Lobus dexter) but some very often have only 1 lobe (unilobe), some 3 (trilobes), and some several lobes (polylobes).

α) Unilobe.

Oncorhynchus, *Plecoglossus altivelis*, *Aplocheilus latipes*, *Monocentris japonicus*, *Scomber japonicus*, *Arctoscopus japonicus*, *Gymnodontes*, Echeneidae, etc. — theirs might be said to consist of 1 lobe.

β) Trilobes.

Katsuwonidae, Thunnidae, Cybiidae, etc. — theirs might be said to have 3 lobes.

γ) Polylobes.

There are often cases in which each lobe of bilobe or trilobe livers is further subdivided and form what may be called the polylobe liver, but there are, however, no representative examples of the sort. The following, however, may perhaps be given as examples of such liver: *Etrumeus micropus*, some Carangidae, *Podothecus*, etc.

δ) Some characteristic forms.

The liver of Cyprinidae has no definite form and may be found half diffused in the spaces between the intestines. The liver of Gobiidae takes the form of a boat or a shovel. Along the edges of the liver of *Scombrops boops* and *Coryphaena hippurus* are characteristic notches, and on the surface of the liver of *Thunnus orientalis* are blood vessels rather thickly diffused.

b. Size.

α) Large livers.

Parasilurus asotus(*Plotosus anguillaris*, small), Apodes, *Sphyraena pinguis*, *Zeus japonicus*, *Beryx splendens*, *Coryphaena hippurus*, *Stromateoides argenteus* (specially large), *Epinephelus septemfasciatus*, Plectognathi (with Monacanthidae heading the list extremely large), *Scorpaenidae*, *Dinogunellus grigorjewi*, *Otophidium asiro*, Gadidae, etc.

β) Small livers.

Spratelloides japonicus, *Salvelinus leucomaenis pluvius*, Salangidae, *Fistularia petimba*, Synentognathi. Mugilidae, Atherinidae, Scombridae (specially small), *Xiphias gladius*, *Therapon oxyrhynchus*, *Siganus fuscescens*, etc.

The form, the weight and the colour of the liver seem to vary a great deal individually and seasonally, but I did not make a detailed study at present.

c. Position.

When it is a unilobe liver, it is located either above or below the stomach, or on the right or left side of it. When it has more than 2 lobes, it usually overhangs the stomach or takes the position of lifting it from below. In the case of a trilobe liver, the left and right lobes are located on the right and left sides of the stomach respectively. In this connection, I noticed that in most cases, the left lobe is larger than the right, and that there are comparatively few instances in which the right lobe is larger than the left. In my opinion, this is worth noting. Another interesting fact was noted in the case of Pleuronectidae: regardless of whether their eyes are on the left or right side of the body, the liver is always on the left side of the stomach.

The form of the peritoneal cavity restricts the form of the liver, that is, it is usual for the lobes with those fishes with only slightly compressed peritoneal cavities to be short, but with those with compressed peritoneal cavities, they are longer, the liver being flattened in such a case.

18. Gall-bladder (Pl. XV).

According to Bridge (1922), the gall-bladder is absent in *Trigla*.

a. Form.

Most fishes that came under my observation have a spherical or an ellipsoid gall-bladder but the followings have rather long, elongated ones: Scombridae, Katsuwonidae, Thunnidae, Cybiidae, Trichiuridae, Istiophoridae, Xiphiidae, Coryphaenidae, Bramidae, Stromateidae, Pampidae, Carangidae, Oplegnathidae, Mullidae, Scombropidae, Serranidae, Sciaenidae, Girellidae, Sparidae, Pomadasyidae, Theraponidae, Aplodactylidae, Hexagrammidae, Ophidiidae, *Eleginus navaga* (other Gadidae ellipsoidal).

b. Size.

Those with small gall-bladders are: Engraulidae, Cepolidae and *Pseudoblennius*; and *Beryx splendens*, *Siganus fuscescens*, Plectognathi, Scorpaenidae, Pleuronectidae, Gadidae, Lophiidae, Antennariidae, etc. have large gall-bladders. The gall-bladder of Uranoscopidae is particularly large.

c. Colour.

In most cases yellow or green. In the case of *Engraulis japonicus* blackish grey.

19. Cystic and Bile Ducts.

The longer the cystic duct, the farther away the gall-bladder is from the liver, and the longer the bile duct, the farther away it is from the duodenum, and as the bile duct always opens at the beginning of the duodenum, one may distinguish the stomach and intestine from where it opens.

The cystic and bile ducts of *Siganus fuscescens* are both long. In the cases of *Girella punctata*, Theraponidae, Labridae, Platycephalidae, Scorpaenidae, Pleuronectidae, Lophiidae, etc., the cystic ducts are long but the bile ducts are comparatively short. Cobitidae, Apodes, Plectognathi, Blennidae, Gobiidae, etc. have short cystic ducts, the bile ducts of Cobitidae and Apodes being extremely short. The bile ducts of Clupeidae are long but the cystic ducts are comparatively short.

20. Pancreas.

Of the various vertebrates, the pancreas of teleost is the only one that is not compact in structure. It is diffused on the surfaces of or inside of between the liver and spleen and around the digestive tracts. However, an almost compact structure of the pancreas may be seen exceptionally in *Parasilurus asotus* and Apodes, etc. Thus, it is usually most abundantly found in little gaps made by the bending, circling and winding of the intestine and along the mesentery or in tiny spaces between the pyloric appendages (examples: Sillaginidae, Pleuronectidae, Callyodontidae, Salmonidae).

As the existence of the pancreas depends on the blood vessels for its mainstay, it usually gathers around them in the form of centipedes, if branches, while others take the form of cords.

At first sight, it looks fat, but it is not so hard to distinguish the two macroscopically, although it is almost impossible to expect any amount of accuracy in the matter, the writer is therefore not in a position to discuss this in any detail in my present study and would refer the readers who require this information to the splendid work already accomplished in this respect by Arima and Kubota (1931).

21. Taxonomy of Fish According to the Forms of Digestive System.

Taxonomy of fish was hitherto conducted principally according to external characters and not according to internal characteristics, that is it was not based on the differences of internal organs, and therefore, as the internal characters become more distinct, I am inclined to believe that the taxonomy of fish of tomorrow will be quite different to what it is today. Are there not sufficient reasons for that possibility? As I am not a taxonomist, perhaps I have no right going into a discussion regarding this matter, but as a result of my humble studies, I have raised several questions in my mind as to the truth of some facts, and although I do not propose to do anything about it, I wish to submit them for the consideration of taxonomists.

a. Isospondyli, a group of fish possessing the Mesocoracoid and Orbitosphenoid has been considered an important item in the classification. Besides, the writer found from his present study, that the intestinal mucous membrane of all the fishes belonging to this sub-order consists of transversal folds.

b. The colours of the digestive tracts of *Engraulis japonicus* and *Coilia mystus*, both of the family Engraulidae, are black and red respectively, and while the intestine of the former is extremely long and winds in a characteristic manner, that of the latter runs in a straight line without any turnings. These are big differences, however, as there are others from the same family whose colour of the digestive tract and intestinal length differ materially if they are of different genera, perhaps this difference is a point not worth bothering about from the taxonomic viewpoint and should be questioned when and why there should be such an occurrence in the same genus.

c. The fishes of Apodes do not have any gill-rakers or pharyngeal teeth; the stomachs take the Y-shape form, and there are characteristic notches or short turnings in the lower parts of the intestine. But *Nemichthys* has a heart-shaped stomach and a straight intestine.

d. All those from the family Syngnathidae do not have a tongue, a stomach any teeth, nor gill-rakers, and are very primitive insofar as their digestive systems are concerned.

e. The extremely well developed pharyngeal teeth, the longitudinal zigzag folds of the intestinal mucous membrane and no stomach characterize those from the family Cyprinidae. But the intestinal mucous membrane of the *Cyprinus carpio* alone is distinctly a piece of single net-work, with a liver diffused with the pancreas, constituting thereby a hepatopancreas. These are facts that cannot be overlooked from the taxonomic point of view. Let us now compare the carp with its nearest relative *Carassius auratus*, which is so nearly allied that hybrids are often found between them.

Table 46

	Cyprinus carpio	*Carassius auratus*
Barbels	2 pairs	1 pair
Pharyngeal teeth	1, 1, 3/3, 1, 1	1, 3/3, 1
Intestine	rather long	extremely long
Intestinal mucous membrane	single net-work folds	longitudinal zigzag fold
Pancreas	diffused inside the liver	not diffused inside the liver

f. Scombridae differs somewhat internally from its closely related Katsuwonidae and Thunnidae. This difference has already been detected by Kishinouye (1923): although the latter two have compact masses of pyloric appendages and trilobe livers, Scombridae has pyloric appendages similar to those of Carangidae and an unilobe liver. In addition to this, the intestinal mucous membranes of the latter two consist of some net-work, but Scombridae has an intestinal mucous membrane consisting of longitudinal folds with waved ridges.

g. The jaw teeth and pyloric appendages of Trichiuridae have a very different aspect from those of Katsuwonidae, Thunnidae, Istiophoridae and Xiphiidae.

h. There seem to be two kinds of type in the intestine of *Stromateoides argenteus* — the rather short and broad type and the long and narrow type.

i. Regardless of the N-shape intestinal winding of all other Carangoid fishes, the intestine of *Alectis ciliaris* alone winds in a circular manner. This is a very appropriate example with which to support my view that when the peritoneal cavity is very much compressed, the intestine often assumes the circular or vortical form of winding.

j. Those from the family Gobiidae have various lengths of intestine. Accordingly, there are various types of winding. The stomach, however, is always invariably the same characteristic I-shape.

k. Some Blenniidae have pyloric appendages but some do not. This is a fact worth noting.

l. It is better to classify the family of flat-fish, viz. Heterosomata, into Pleuronectidae and Soleidae, again Pleuronectidae into subfamilies, Pleuronectinae, Hippoglossinae and Psettinae, instead of into Bothidae, Pleuronectidae, Cynoglossidae, etc., because there is a great difference in the features of the digestive systems of Pleuronectinae and Hippoglossinae.

FOOD AND FEEDING HABITS.

In order to obtain a right judgment concerning the natural feeding habits of fishes, we must collect as many materials as possible concerning each species of fish in different seasons and localities, and then analyze the stomach contents minutely.

Consequently several years would be needed if only one person were to be engaged for attaining a correct idea of the feeding habits of the fishes of even one species.

Fortunately, however, quite many results of the research as to the feeding habits of various kinds of fishes have been published by many scholars. I have tried to combine these results with my own to gain a correct judgment. Through such a procedure I have completed my inquiry in connection with the food and feeding habits of teleosts.

In the present study I have chiefly dealt with the food of the fishes on point of qualitative view, because at present the problem of food for so many fishes has not been sufficiently solved yet even from the point of qualitative view; therefore I consider it to be premature to begin with the quantitative study at such a period.

1. Classification of the Feeding Habits.

Excluding several species, various substances are found in the stomachs of fishes when they are cut opened. Picking out extreme cases the following statements are read: letters (Fishing News, 1930, 25), spoons (Ibid, 1927, 21), diamond (Fishing Gazette, 1918, 10; Fishing News, 1930, 22) etc. were found in them, curious to say.

In speaking *Siganus fuscescens*, a fish considered purely a herbivorous, is caught sometimes by bait of clam-worms, also *Trichiurus haumela*, a sea fish, by loach a fresh-water fish. So opinions prevail that fishes eat anything that comes along.

If we investigate the feeding habits of fishes from similar angle, namely, through their principal food, differentiation is easily seen; accordingly a suitable classification is brought forth. Moreover, a suitable classification is possible by the way of establishment of a larger category instead of a traditional classification, namely jamming up many into a small group as scholars have been doing.

Now I will state the results obtained from the present study in regard to the classification of the food and habits of the fishes in a form of table (See Table 47).

a. Fresh-water region.

The fishes living in the region are Cyprinidae, Salmonidae, Siluridae and Cobitidae, etc., and on the other hand, insects, their larvae, micro-crustaceans and diatoms, etc. to be produced in fresh-water, are bred in the region, therefore their food is mostly limited within this sphere. It is noteworthy, however, that the region of fresh-water is liable to cause subsiding, freezing or reducing food supply, and that as the living conditions over there are not so good compared with other regions, so they have to be patient with scantiness of their food, and even they abstain from food during winter, or they have to take the food that are at hand, that is. omnivorous.

b. Blackish water region.

As the most fishes living in this region can live in fresh-water as well as in coastal water, the physical adaptation is vigorous; thus they have eqally omnivorous habits. Nevertheless, ebbing or flowing of tide affect upon the course of the water, quality of the water and the species or quantity of plankton and the consequence is spasmodic food taking in accordance with the tidal variation.

c. Coastal region.

Owing to the fact that creatures as food for fishes are distributed in the region most abundantly and uniformly, we find in this region such fishes as shaped to have comparatively slowness in swimming velocity. Therefore we find there various fishes which are manifold in their food and their modes of catching food.

α) Tidal pool.

Here live mostly young fishes, and *Chasmichthys* is a sole adult fish found here. This fish lives on rock-slater and green-algae etc., and it eats even its own youngs and the reason is assumed to be due to the scantiness of the creatures to be found for the food of this fish.

β) Upper and middle layer.

In this region are found abundantly zoo-plankton, phyto-plankton or larval fishes; thus sardines and mackerels or others take these creatures without special efforts whatever. As sardines live in swarm both in coastal or oceanic regions, large fishes living in the neighbourhood are fond of sardines, that is to say, *Seriola* or *Sawara niphonia* feeds principally on sardines in the region. A special attention is called for the fact that *Psenopsis anomala*, *Stromateoides argenteus* and some others take jelly-fishes as their usual food. *Periophthalmus cantonensis* is peculiar somewhat: the fish catches crawling crabs, *Ligida* and others around there by way of jumping on the beach.

γ) Around rocks.

Here are found Oplegnathidae or Monacanthidae, etc. which have strong jaw-teeth, and take the hard food such as *Balanus* which attaches itself to rocks; *Girella punctata*, *Leptoscarus japonicus*, *Siganus fuscescens*, etc. take sea-weeds growing on rocks; Sparidae, Tetraodontidae, etc. eat omnivorously living things that gather around rocks; Congridae, Muraenidae, or the like have sharp jaw-teeth, and hide themselves behind rocks or in the mud in the day-time but come out in the night to attack large fishes or macro-crustaceans.

δ) Between weeds.

Here we find Syngnathidae which take micro-crustaceans using their long snout like a pipette because of destitution of teeth; also *Ditrema temmincki* which eats spectre-shrimps that attach to sea-weeds. And, as this region is the breeding place of various young fishes, Carangioid and Blennoid fishes, etc. wander about there to search after them for their food. *Pterophryne histrio* whose colour is ambiguous to that of sea-weed, hides usually between weeds and attacks the young fishes which come up there.

ε) Bottom.

The fishes living here need not work much especially for food, and the extreme weakness of their swimming power is obvious as a result of it. Another noticeable thing is Lophiidae that stays still in the bottom of the sea and catches fishes attracting them by lures above his own head.

Those which eat exclusively the bottom fishes are Muraenesocidae, *Zeus japonicus*, *Lotella phycis*, etc.; and those which selectively aim at young fishes or small Crustacea (Amphipoda, Isopoda, etc.) are Apogonidae, Sciaenidae, Sillaginidae, etc.; and those which eat shell-fishes, clam-worms, brittle-stars, sea-urchins, etc. that are produced plentifully in this region in addition to young fishes, small Crustacea, or others, are as follows: *Leiognathus nuchalis*, *Goniistius zonatus*, Monacanthidae, Platycephalidae, Trigridae, Pleuronectidae, etc.

As the noteworthy characters of the feeding habits or adaptation of the fishes living in this region may be mentioned as follows: they have protrusile jaws for the purpose of catching minute food in the muddy bottom as

Table

Habitat / Usual food	Fresh-water region	Blackish-water region	Coastal-water		
			Tide pool	Upper and middle layer	Around rock
Algae					*Siganus fuscescens*
Algae+Mud		*Mugil cephalus*		*Mugil cephalus*	
Algae+Shell-fish					*Leptoscarus japonicus*
Algae+Polychaeta					*Girella punctata*
Diatom				*Engraulis japonicus* *Boleophthalmus pectinirostris*	
Diatom+Blue-algae	*Plecoglossus altivelis*				
Diatom+Micro-Crustacea	*Hypomesus olidus*	*Harengula zunasi*		*Sardinia melanosticta*	
Diatom+Micro-Crustacea+Mud		*Clupanodon punctatus*		*Clupanodon punctatus*	
Insect (adult, larvae)	*Salvelinus pluvius*				
Insect+Micro-Crustacea	*Oncorhynchus nerka* *Oncorhynchus masou* *Gnathopogon caerulescens* *Sarcocheilichthys variegatus*				
Insect+Micro-Crustacea+Mud	*Misgurnus anguillicaudatus* *Cobitis biwae*				
Micro-Crustacea		*Coilia mystus* *Salangichthys microdon*		*Clupea pallasii* *Hemirhampus sajori* *Atherina bleekeri* *Atherina tsurugae* *Scomber japonicus*	
Micro-Crustacea+Larval fish				*Etrumeus micropus* *Oncorhynchus nerka* *Oncorhyuchus masou* *Sphyraena pinguis*	*Trachurus japonicus* *Sebastodes inermis* *Sebasticus marmoratus* *Pterogobius elapoides*
Micro-Crustacea+Polychaeta					
Micro-Crustacea+Gastropoda+Polychaeta					
Polychaeta+Diatom					
Micro-Crustacea+Fish, etc.	*Parasilurus asotus*				*Astroconger myriaster* *Alloconger anagoides* *Gymnothorax kidako*
Fish (adult, larvae)				*Athlenna anastomella*	*Decapterus muroadsi*
Bottom fish					
Deep-sea fish, etc.					
Lantern fish					

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region		Oceanic region		Deep-sea region	
Among weeds	Bottom	Upper and middle layer	Around rock	Middle layer	Around rock
Trachurus japonicus *Decapterus muroadsi*					
Syngnathus schlegeli *Hippocampus coronatus*	*Acanthocepola krusensterni* *Podothecus acipenserinus* *Ammodytes personatus*			*Dasiscopelus spinosus* *Trachypterus iris* *Theragra chalcogramma*	
Fistularia petimba *Alectis ciliaris*	*Arctoscopus japonicus* *Apogon lineatus* *Apogon semilineatus*				
	Upeneus bensasi				
		Cypsilurus agoo			
		Cololabis saira			
	Muraenesox cinereus				
Enedrias nebulosus *Pterophryne histrio*	*Zeus japonicus* *Trichurus haumella*	*Katsuwonus vagans* Thunnidae *Sawara niphonia* *Xiphias gladius*			*Brama raii*
		Nibea mitsukurii *Nibea argentata* *Lotella phycis* *Lophius litulon*			
					Scombrops boops
					Beryx splendens

Fish+Cuttle-fish				*Seriola quinqueradiata*	
Lantern fish+Cuttle-fish+Crustacea					
Jelly-fish				*Stromateoides argenteus* *Psenopsis anomala*	
Small animal of beach				*Periophthalmus cantonensis*	
Rock-slater+Own young, etc			*Chasmicthys*		
Bottom-living creature					
Caprella+Bottom-living creature					
Bottom-living creature+Egg				*Plotosus anguillaris*	
Various creatures around rock					*Oplegnathus fasciatus* *Oplegnathus punctatus* *Pseudoblennius percoides* *Monacanthus cirrhifer*
Various kinds of vegetable and animal matters	*Tribolodon hakonensis* *Carassius auratus* *Cyprinus carpio* *Anguilla japonica*	*Tribolodon hakonensis* *Anguilla japonicus*			*Epinephelus septemfasciatus* Sparidae Tetraodontidae
Dead animal+Mud					
Dropped food of large fish					

in the cases of *Leiognathus nuchalis*, Sillaginidae, and others; some have their mouths in lower part of the heads instead of terminal part as seen in the cases of Platycephalidae, *Podothecus*, Triglidae, etc. or others; some like Pleuronectidae, have larger cleft of mouth on the side where eyes lack, and also well developed teeth; and finally, some have, for instance, *Upeneus bensasi*, *Lotella phycis*, barbels about their mouths, with which they are able to feel the whereabouts of food by touching.

d. Oceanic region.

In the region, food is far less than the region mentioned above, except the rocky bottom. Especially in the upper and middle layers, sardines, a few other fishes or a school of cuttle-fishes live scattered only; consequently the fishes living in the region, particularly the fishes migrating in the upper layer, have few chances to find their food; thus they are forced to have immense swimming power, with which they migrate to distant places, and the best examples are *Makaira mitsukurii*, *Xiphias gladius*, *Katsuwonus vagans*, Thunnidae etc. The writer has found in the present study that these fishes

		Makaira mitsukurii *Coryphaena hippurus*	*Stereolepis ischinagi*	
				Sebastodes flammeus *Sebastodes matsubarae* *Sebastodes iracundus* *Sebastodes baramenuke*
		Mola mola		
Therapon oxyrhynchus	*Leiognathus nuchalis* *Hapalogenys mucronatus* *Goniistius zonatus* *Monacanthus cirrhifer* *Aracana aculeata* *Inimicus japonicus* *Hexagrammos otakii* *Agrammus agrammus* *Platycephalus indicus* *Lepidotrigla microptera* Pleuronectidae		*Branchiostegus japonicus*	*Gadus macrocephalus*
Ditrema temmincki				
			Katsuwonus vagans Thunnidae *Xiphias gladius* *Canthidermis rotundatus*	
	Halichoeres poecilopterus *Pseudolabrus japonicus*			
	Trypauchen			
		Echeneis brachyptera		

live in the vicinity of rocky bottoms for a certain duration of time feeding on the fishes roundabout or Crustacea, but when a time comes they begin to migrate to and fro in the upper layer covering a long distance. At this juncture they change their food from those mentioned above to sardines or cuttle-fishes.

Besides, planktonic Crustacea or Gastropoda are eaten by *Cypsilurus agoo*; flying-fishes, cuttle-fishes, or sometimes even *Lepas* attached to floating lumbers, by *Coryphaena hippurus*; and jelly-fishes, by *Mola*; Crustacea living rocky bottoms, by *Branchiostegus japonicus* exclusively.

e. Deep-sea region.

Owing to insufficient material at present the knowledge of the habits of the deep-sea fishes are exceedingly meagre, but it seems, so far at present, that most of them live near the bottom in the deep-sea and they come up at night towards the surface doing vertical migration. The reason why they do so is presumably due to the fact that small crustaceans, the staple food for Myctophidae for instance, stay in the deep in the daytime and comes up near the surface in the night, accordingly deep-sea fishes migrate vertically in the deep-sea.

At the present research it is presumed that the usual food for ***Beryx splendens***, ***Scombrops boops*** and Scorpaenidae is Myctophidae, therefore the vertical migration of Myctophidae will induce the vertical migration of those fishes mentioned above.

Gadus macrocephalus living on comparatively shallow bottom is a typical voracious fish devouring all kinds of bottom-fishes, macro-crustaceans, Polychaeta, or shell-fishes, etc. On the contrary *Theragra chalcogramma* living always in the middle layer rather than the bottom, prefers micro-crustaceans.

2. Miscellaneous Notes.

The above-mentioned is a general view of the usual food of fishes; but the feeding habits quite differ in accordance with locality, season, age or sexes, especially a remarkable differentiation is effected by age, young or old. I will show some few examples: *Siganus fuscescens*, typically a herbivorous fish, lives on micro-crustaceans in the young stage; and *Plecoglossus altivelis* that eats particularly diatoms or blue-algae in rivers in the adult begins to feed vigorously on copepods in the young stage in the sea. Thus almost all fishes show more or less the transition of food with age. For the said occurrence I have called the attention in my preliminary report published in 1935 to the point that "the feeding habits of the adult character are begun when every organ of the digestive system has been completed."

Another important item in regard to the feeding habits is a fact that some fishes fast during the winter season; the examples are shown by many fresh-water fishes and *Halichoeres poecilopterus*, *Periophthalmus cantonensis*, *Boleophthalmus pectinirostris, etc.* Again some fishes fast during their spawning season, for instance, some of Salmonoid fishes, *Upeneus bensasi*, *Ditrema temmincki*, etc.

Conclusion

Jacobshagen (1913), who spent 6 years to make a morphological study of the stomach, intestine and pyloric appendages of some 100 species of fishes found in European waters, stated frankly in the concluding part of his paper that the result of his research was not so much interesting as he had expected. I have too just similar feeling after studying the digestive system and feeding habits of some 150 species of Japanese fishes, yet, in my case by following a special procedure for my own research, I was able to obtain some interesting and positive results.

In order to explain the conclusion as concisely as possible, I prepared Table 48, picking up only those fishes which have distinctive characteristics.

In the table, signs A, a, B, b, etc. are simply for convenience's sake, and where capital and small types of the same letter are used for indicating opposite characters;. for instance, large mouth is shown by capital letter A, whereas small mouth by small letter a, and so on, and i~n indicates the opposite characters of I, J, K, L, M and N, meaning that the jaw-teeth are wanting or only rudimentary. Letters with and without dashes (′) show the difference in character; for example, A indicates fish with large mouth which is used for taking large size food, while A′ indicates that with equally large mouth which, however, is used for taking large quantity of food; P indicates fish with developed pharyngeal teeth which is used for grinding hard food, whereas P′ indicates that which is used for cutting such food as jelly-fish into small pieces.

1) Fishes like Thunnidae, Katsuwonidae, etc. which swallow their food whole are given great swimming power (V) and developed stomach (R) to take in a large quantity of food within a short time. Thus, the feeding habits of those fishes may be determined by V+R.

2) Fishes like *Muraenesox cinereus, Trichiurus haumela*, etc. which do not have such great swimming power as those mentioned above, have developed jaw-teeth (I) so as to enable them to hold their food once they get, which fact has a close connection with their feeding habits. In the case of *Engraulis japonicus*, a diatom feeder, there are several factors, A′+i~n+Q+S. Thus, the feeding habits may be in some cases be explained by a single organ or a few organs, and sometimes necessarily by several organs of the digestive system combined.

3) Among the fishes which find their food in muddy bottom, such as Trigridae, Mullidae, Cobitidae, etc. have a mouth directed downwards (b), while *Leiognathus nuchalis*, etc. have a protrusile jaws (D), and Pleuronectinae or Cynoglossidae a bilaterally asymmetrical mouth (C). Among the fishes which possess the habits of biting off the hard food on rocks, such as Plectognathi and *Leptoscarus japonicus* have developed incisor-like teeth (K), while *Oplegnathus fasciatus* have soldered teeth (L).

4) In some cases the digestive organ shows much the sign of developmental features in accordance with the phylogeny of the species. Among others, *Cyprinus carpio*, a fish of Cyprinidae, is an example. As fishes of Cyprinidae are those devoid of stomach phylogenically, the fish does not possess the stomach no matter how it may be useful, and instead has specially developed pharyngeal teeth.

5) By far the most fishes possess digestive organs showing good adaptation to the mode of feeding. For instance, plankton-feeders, such as *Engraulis japonicus, Clupanodon punctatus* and *Sardinia melanosticta*, are furnished with specially fine and closely set gill-rakers for sieving and highly developed pyloric part of stomach for digesting of their food, the diatoms.

6) The digestive system of adult fishes is constructed as being in accordance with their phylogeny on one hand and much depending on the food and feeding habits on the other. So, the relation between the digestive system and feeding habits exists insofar as the phylogeny of its possessor allows its modification and differentiation for the adaptation to the feeding. Therefore, fishes which have the same feeding habits do not necessarily show the same construction of digestive system, which fact is the reason why the feeding

Table

		Carnivora ←															
Feeding habits		Pursuits of food					Waits for food			Very voracious	Feeds on hard food, such as shell-fishes, crabs, etc	Hunts for food in the muddy bottom					
		Swallows food whole		Holds food by biting			Feeds principally on dropped food of large fishes	Entices fishes about mouth									
Representative species		Thunnidae, *Makaira mitsukurii*, *Xiphias gladius*	Katsuwonidae, *Seriola quinqueradiata*	*Sawara niphonia*, *Scombrops boops*	*Muraenesox cinereus*, *Gymnothorax kidako*, *Trichiurus haumela*	*Athlennes anastomella*	Echeneidae	Lophiidae	Antennariidae	*Gadus macrocephalus*, *Pseudoblennius percoides*	*Pagrosomus major*, *Sparus swinhonis*	Platycephalidae	*Leiognathus nuchalis*, *Cyprinus carpio*	Pleuronectinae, Cynoglossidae	Trigridae, Agonidae	Mullidae	Cobitidae
Digestive System																	
Mouth	Large				A	A	A	A	A	A′							
	Small																
	Directed upwards						B	B	B								
	Directed downwards														b	b	b
	Bilateral asymmetry													C			
Jaw	Protrusile												D				
	Long					E											
	Tube-like																
With barbel(s)																G	G
With tentacle or antenna								H	H								
Jaw teeth	Canine-like teeth developing			I	I	I	I	I									
	Molar-like teeth developing										J						
	Incisor-like teeth developing																
	Soldered teeth																
	Tricuspid teeth developing																
	Comb-like teeth developing																
	None or rudimentary	i∼n	i∼n														
Teeth on tongue, vomer and palatine							O										
Pharyngeal teeth	Developing										P	P	P	P	P		
	None or rudimentary	p															
Gill-raker	Closely set																
	None or transformed				q			q	q								
Stomach	Developing	R	R	R	R			R	R	R							
	None or rudimentary												r	r			r
	Pyloric part muscular																
With fore-stomach																	
Intestine	Long																
	Short				u	u	u										
Swimming power	Very powerful	V	V														
	Not so good				W	W	W	W	W			W		W	W		W
With protecting-colour								X	X								

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— → Herbivora

Feeds principally on jelly-fish			Bites off animals on rocks			Feeds on macro-plankton			Feeds on micro-plankton			Feeds principally on diatoms			Feeds on algae	
															Feeds fairly on algae	Feeds principally on algae
Stromateoides argenteus	*Psenopsis anomala*	*Mola mola*	*Leptoscarus japonicus*	Plectognathi	*Oplegnathus fasciatus*	*Cypsilurus agoo, Trachurus japonicus, Alectis ciliaris*	*Etrumeus micropus, Ammodytes personatus*	*Cololabis saira*	Fistularidae, Syngnathidae	*Plecoglossus altivelis*	*Clupanodon punctatus, Sardinia melanosticta*	*Engraulis japonicus*	*Mugil cephalus*	*Periophthalmus cantonensis*	*Girella punctata*	*Siganus fuscescens*
												A′	A′	A′		
				a	a	a	a	a	a							
													h			
									F							
			K	K												
					L											
															M	
										N						
						i∼n	i∼n	i∼n	i∼n		i∼n	i∼n	i∼n			
	P′	P′	P													
									p	p	p	p		p		
							Q	Q		Q	Q	Q	Q			
			r	r				r	r							
											S	S	S			
T	T															
U											U	U	U	U	U	U
W	W	W	W	W	W											

habits of fishes cannot always be explained by the feature of any single organ, and in some cases many characters combined should be taken into consideration for the elucidation of the feeding habits.

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Explanation of Plates

Plate I

Various kinds of jaw teeth.

Fig. 1. Degenerated teeth of *Seriola quinqueradiata.*
Fig. 2. Sharp teeth of *Trichiurus haumela.*
Fig. 3. The same of *Scombrops boops.*
Fig. 4. The same of *Athlennes anastomella.*
Fig. 5. Hinged teeth of *Lophius litulon.*
Fig. 6. The same of *Gadus macrocephalus.*
Fig. 7. Stout teeth of *Pseudolabrus japonicus.*
Fig. 8. Soldered teeth of *Oplegnathus fasciatus.*
Fig. 9. The same of *Leptoscarus japonicus.*
Fig. 10. Incisor-like teeth of *Monacanthus cirrhifer.*
Fig. 11. Molar teeth of *Pagrosomus major*
Fig. 12. Tricuspid vomerine teeth of *Muraenesox cinereus.*
Fig. 13. Teeth on palatine of *Dinogunellus grigorjewi.*
Fig. 14. Comb-like jaw-teeth of *Plecoglossus altivelis.*

Plate II

Pharyngeal teeth.

Fig. 1. *Ditrema temmincki.*
Fig. 2. *Pagrosomus major.*
Fig. 3. *Leptoscarus japonicus.*
Fig. 4. *Mola mola.*

Plate III

Various kinds of tongues.

Fig. 1. Triangular tongue of *Sillago sihama.*
Fig. 2. The same of *Pseudoblennius percoides.*
Fig. 3. Trianguloid tongue of *Apogon lineatus.*
Fig. 4. The same of *Clupea pallasi.*
Fig. 5. Semi-elliptic tongue of *Gadus macrocephalus.*
Fig. 6. The same of *Sebastiscus inermis.*
Fig. 7. Rectangular tongue of *Nibea mitsukurii.*
Fig. 8. The same of *Cololabis saira.*
Fig. 9. Long stretched tongue of *Fistularia petimba.*
Fig. 10. Rimmed tongue of *Plecoglossus altivelis.*
Fig. 11. Racket-form tongue of *Astroconger myriaster.*
Fig. 12. Pyramidal tongue of *Sparus swinhonis.*
Fig. 13. Square-fan-form tongue of *Platycephalus indicus.*
Fig. 14. Soft tongue of *Pterophryne histrio.*
Fig. 15. The same of *Zeus japonicus.*
Fig. 16. Toothed tongue of *Coryphaena hippurus.*
Fig. 17. Lateral view of tongue of *Cololabis saira.*

Plate IV

Various kinds of gill-rakers.

Fig. 1. Degenerated gill-rakers of *Anguilla japonica.*
Fig. 2. Rudimentary gill-rakers of *Misgurnus anguillicaudatus.*
Fig. 3. *Parasilurus asotus.*
Fig. 4. *Monacanthus cirrhifer.*
Fig. 5. *Hexagrammos otakii.*
Fig. 6. *Sillago sihama.*
Fig. 7. *Epinephelus septemfasciatus.*
Fig. 8. *Branchiostegus japonicus.*
Fig. 9. *Oncorhynchus keta.*
Fig. 10. *Seriola quinqueradiata.*
Fig. 11. *Clupea pallassii.*
Fig. 12. Fine gill-rakers of *Clupanodon punctatus.*
Fig. 13. *Uranoscopus japonicus.*
Fig. 14. *Inimicus japonicus.*
Fig. 15. *Zeus japonicus.*
Fig. 16. Soft gill-rakers of *Boleophthalmus pectinirostris.*
Fig. 17. Folked gill-rakers of *Siganus fuscescens.*
Fig. 18. Characteristic gill-rakers of *Trichiurus haumela.*

Plate V

Various kinds of stomach.

Fig. 1. I-shape stomach of *Salangichthys microdon.*
Fig. 2. The same of *Trypauchen vagina microcephalus.*
Fig. 3. The same of *Sphaeroides vermicularis.*
Fig. 4. Curved I-shape stomach of *Paralichthys olivaceus.*
Fig. 5. U-shape stomach of *Oncorhynchus keta.*
Fig. 6. V-shape stomach of *Pagrosomus major.*
Fig. 7. The same of *Hapalogenys mucronatus.*
Fig. 8. The same of *Siganus fuscescens.*
Fig. 9. Y-shape stomach of *Sardinia melanosticta.*
Fig. 10. ┐-shape stomach of *Branchiostegus japonicus.*
Fig. 11. The same of *Sebastodes baramenuke.*
Fig. 12. The same of *Ammodytes personatus.*

Plate VI

Various kinds of gastric mucous membrane.

Fig. 1. *Sardinia melanosticta*: cardiac part of stomach.
Fig. 2. Ibid.: blind sac.
Fig. 3. Ibid.: pyloric part.
Fig. 4. *Branchiostegus japonicus.*
Fig. 5. *Etrumeus micropus.*
Fig. 6. *Hypomesus olidus.*
Fig. 7. *Sillago sihama.*
Fig. 8. *Kareius bicoloratus.*

Plate VII

Various kinds of gastric mucous membrane, continued.

Fig. 9. *Sebastodes matsubarae.*
Fig. 10. *Trichiurus haumela.*
Fig. 11. *Misgurnus anguillicaudatus.*
Fig. 12. *Anguilla japonica.*
Fig. 13. *Gadus macrocephalus.*
Fig. 14. *Pagrosomus major.*
Fig. 15 *Clupea pallasii.*
Fig. 16. *Lepidotrigla microptera.*

Plate VIII

Diagrammatic illustration of intestinal winding. The type varies according to length of intestine and size of peritoneal cavity.

Fig. 1 *Syngnathus schlegeli.*
Fig. 2. *Nibea mitsukurii.*
Fig. 3. Congridae.
Fig. 4. *Ammodytes personatus.*
Fig. 5. *Enedrias nebulosus.*
Fig. 6. *Atherina bleekeri.*
Fig. 7. Thunnidae.
Fig. 8. *Platycephalus indicus.*
Fig. 9. *Scomber japonicus.*
Fig. 10. *Sardinia melanosticta.*
Fig. 11. *Branchiostegus japonicus.*
Fig. 12. *Hippocampus coronatus.*
Fig. 13. *Epinephelus septemfasciatus.*
Fig. 14. *Engraulis japonicus.*
Fig. 15. *Cyprinus carpio.*
Fig. 16. *Kareius bicoloratus.*
Fig. 17. *Monacanthus cirrhifer.*
Fig. 18. *Siganus fuscescens.*
Fig. 19. *Leiognathus nuchalis.*
Fig. 20. *Aplocheilus latipes.*
Fig. 21. *Xiphias gladius.*
Fig. 22. *Boleophthalmus pectinirostris.*
Fig. 23. *Stromateoides argenteus.*
Fig. 24. *Girella punctata.*
Fig. 25. *Mola mola.*
Fig. 26. *Carassius auratus.*
Fig. 27. *Mugil cephalus.*

Plate IX

Various kinds of intestinal mucous membrane.

Fig. 1. *Misgurnus anguillicaudatus.*
Fig. 2. *Nibea mitsukurii.*
Fig. 3. *Gadus macrocephalus.*
Fig. 4. *Scomber japonicus.*
Fig. 5. *Carassius auratus.*
Fig. 6. *Ditrema temmincki.*
Fig. 7. *Scombrops boops.*
Fig. 8. *Clupea pallasii.*

Plate X

Various kinds of intestinal mucous membrane, continued.

Fig. 9. *Oncorhynchus keta.* Lower part of middle intestine.
Fig. 10. *Plecoglossus altivelis.*
Fig. 11. *Fistularia petimba.*
Fig. 12. *Cyprinus carpio.*
Fig. 13. *Gymnothorax kidako.*
Fig. 14. *Trichiurus haumela.*
Fig. 15. *Stereolepis ischinagi.*
Fig. 16. *Oncorhynchus keta.* Middle part of intestine.

Plate XI

Various kinds of intestinal mucous membrane, continued.

Fig. 17. *Anguilla japonica.*
Fig. 18. *Goniistius zonatus.*
Fig. 19. *Lateolabrax japonicus.*
Fig. 20. *Pagrosomus major.*
Fig. 21. *Astroconger myriaster.*
Fig. 22. *Cololabis saira.*
Fig. 23. *Echeneis brachyptera.*
Fig. 24. *Seriola quinqueradiata.*

Plate XII

Various kinds of intestinal mucous membrane, continued.

Fig. 25. *Cypsilurus agoo.*
Fig. 26. *Mugil cephalus.*
Fig. 27. *Branchiostegus japonicus.*
Fig. 28. *Sphaeroides vermicularis.*
Fig. 29. *Girella punctata.*
Fig. 30. *Kareius bicoloratus.*
Fig. 31. *Sebastiscus marmoratus.*
Fig. 32. *Lottela phycis.*

Plate XIII

Specially long or short pyloric appendages.

Fig. 1. *Decapterus muroadsi.*
Fig. 2. *Beryx splendens.*
Fig. 3. *Branchiostegus japonicus.*
Fig. 4. *Pagrosomus major.*
Fig. 5. *Girella punctata.*

Fig. 6. *Ammodytes personatus.*
Fig. 7. *Trachypterus iris.*

Plate XIV

Characteristic pyloric appendages

Fig. 1. *Brama rau.*
Fig. 2. *Saurida undosquamis.*
Fig. 3. *Psenopsis anomala.*
Fig. 4. *Sawara niphonia*
Fig. 5. *Xiphias gladius.*

Plate XV

Various kinds of gall-bladder

Fig. 1. *Paralichthys olivaceus.*
Fig. 2. *Sphaeroides vermicularis.*
Fig. 3. *Lophius litulon.*
Fig. 4. *Beryx splendens.*
Fig. 5. *Scombrops boops.*
Fig. 6. *Uranoscopus japonicus.*

Correction: B) Jaw teeth in Fig. 106 on p. 155, should be
B) Pharyngeal teeth.

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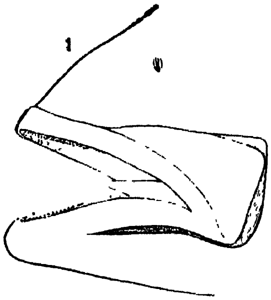

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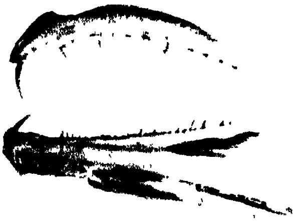

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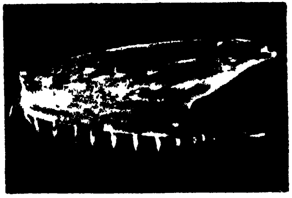

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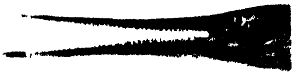

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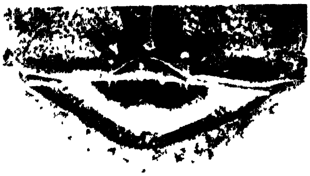

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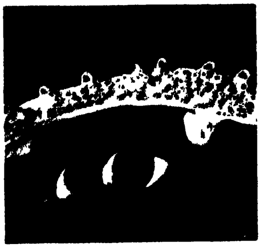

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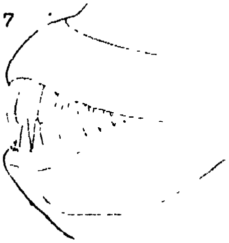

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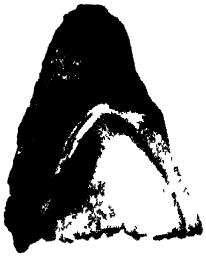

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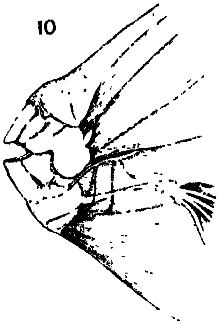

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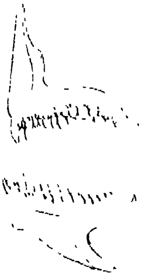

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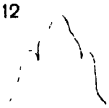

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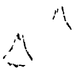

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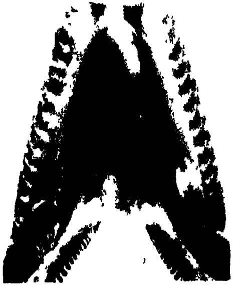

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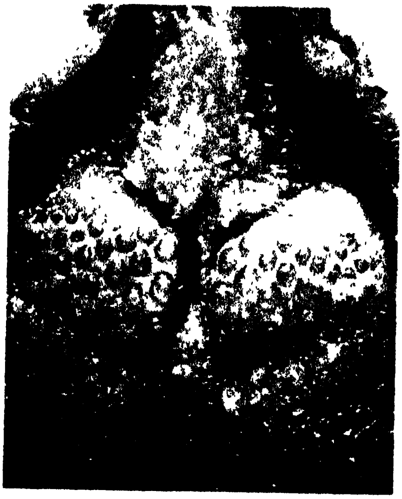

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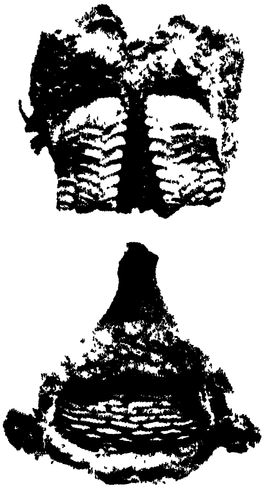

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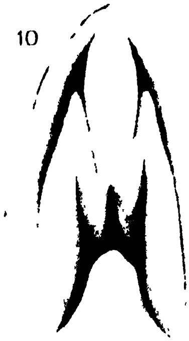

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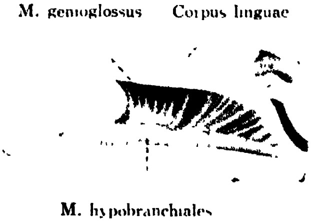

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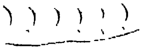

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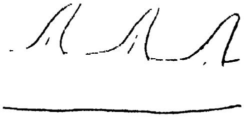

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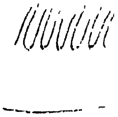

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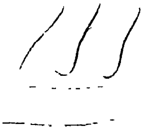

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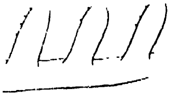

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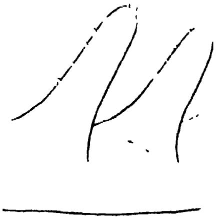

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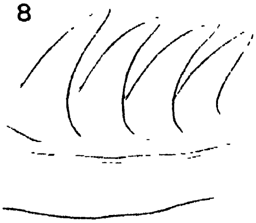

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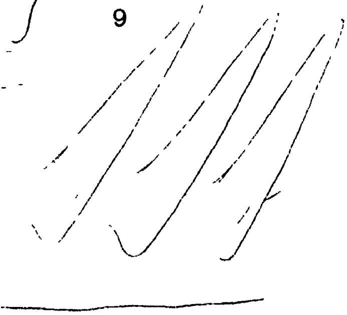

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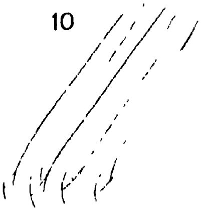

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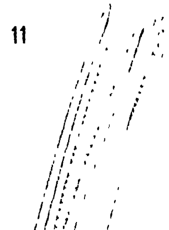

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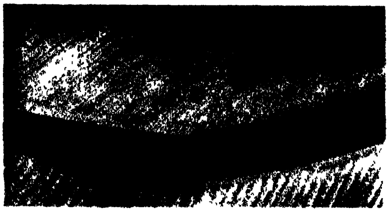

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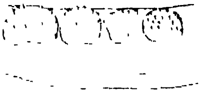

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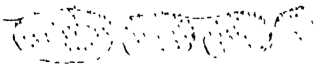

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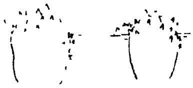

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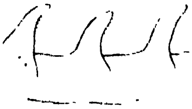

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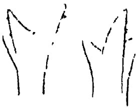

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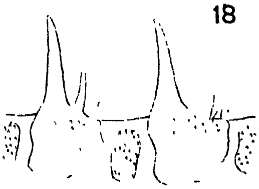

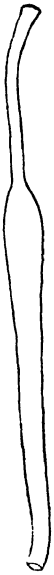

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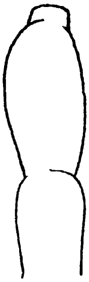

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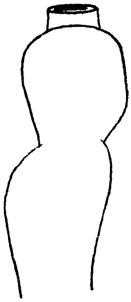

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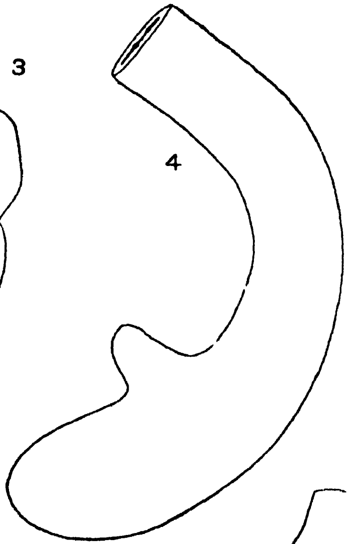

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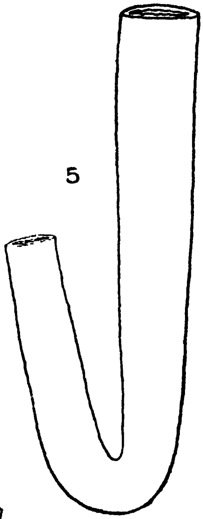

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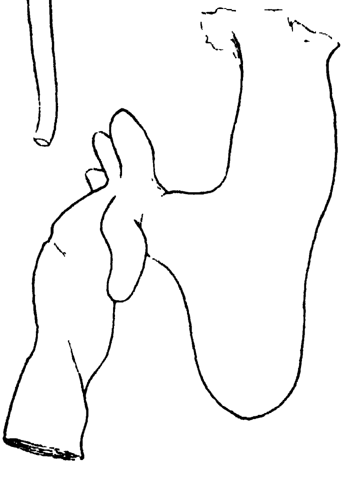

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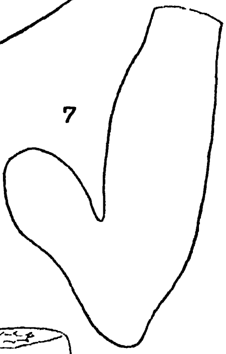

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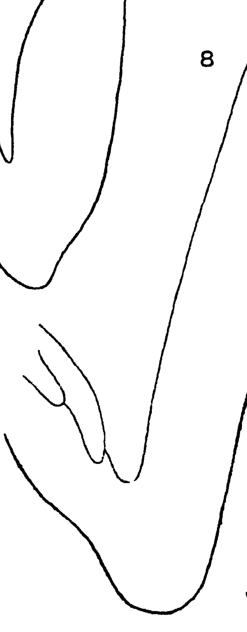

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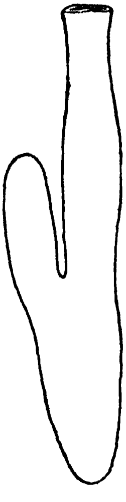

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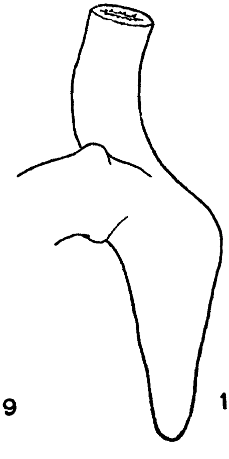

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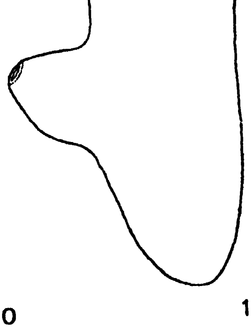

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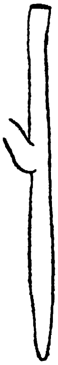

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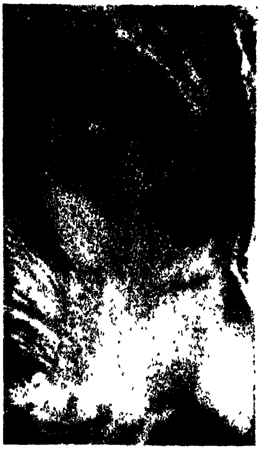

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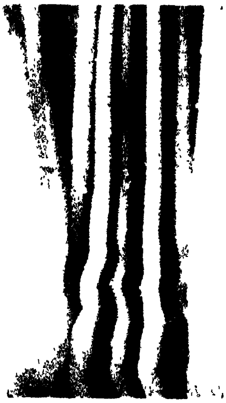

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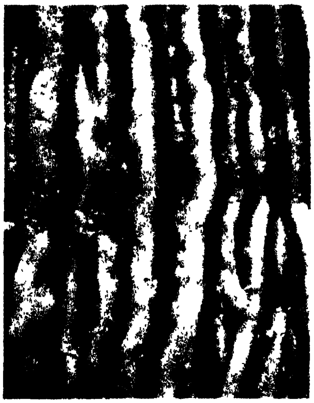

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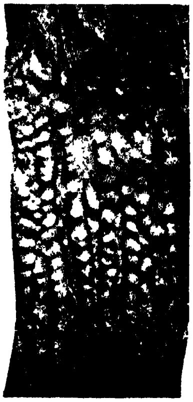

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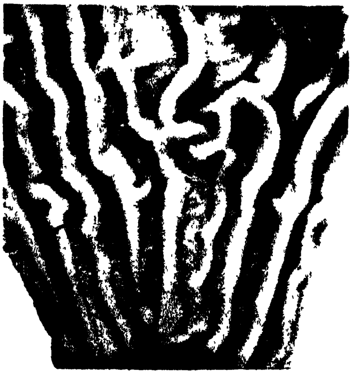

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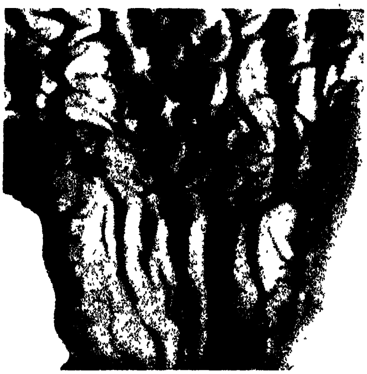

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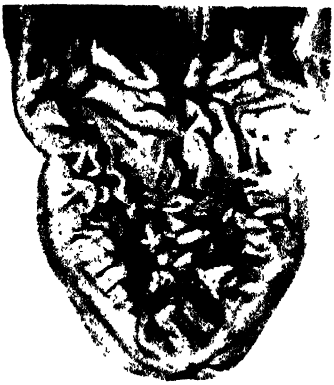

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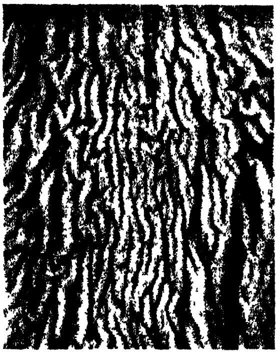

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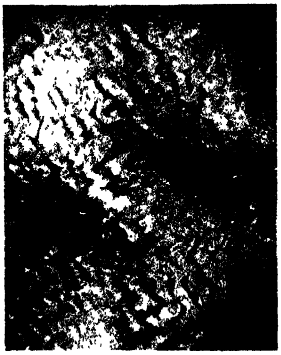

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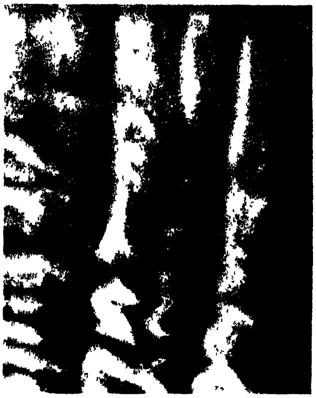

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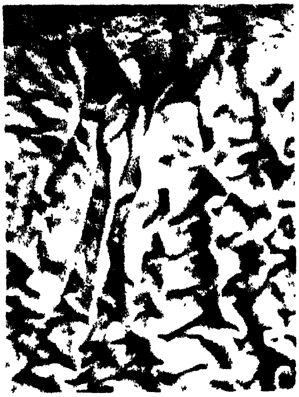

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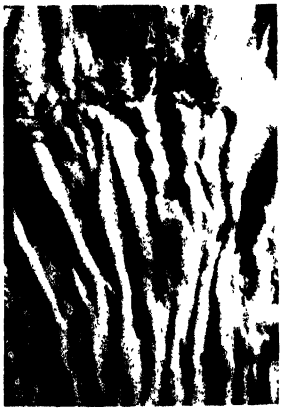

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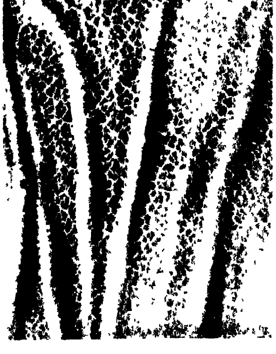

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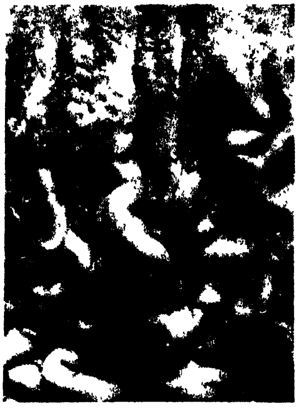

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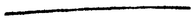

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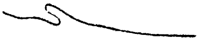

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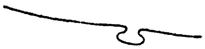

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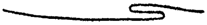

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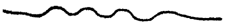

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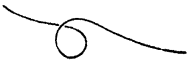

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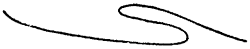

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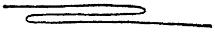

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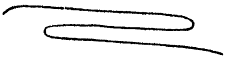

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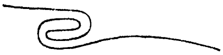

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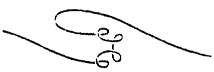

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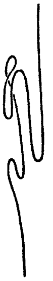

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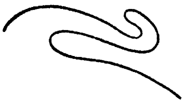

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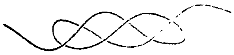

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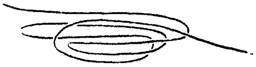

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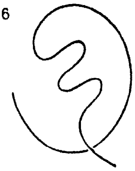

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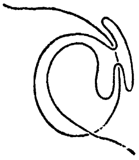

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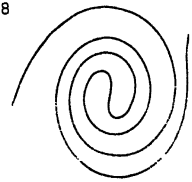

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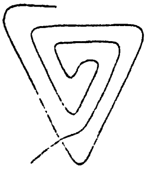

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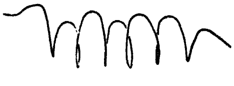

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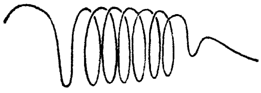

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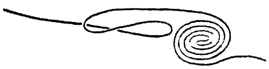

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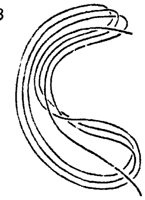

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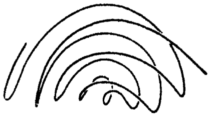

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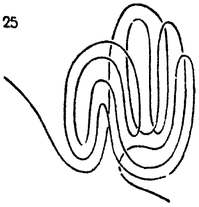

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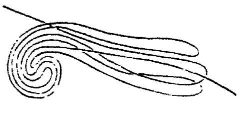

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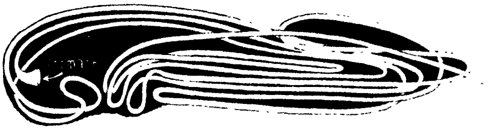

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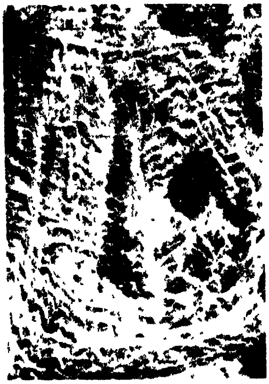

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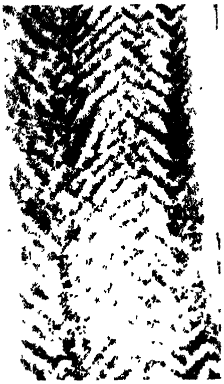

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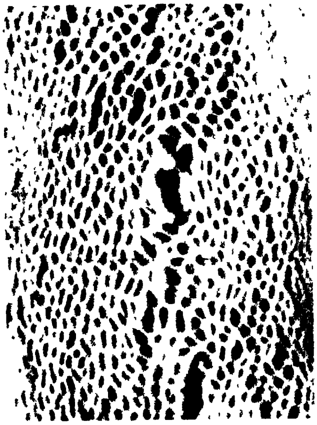

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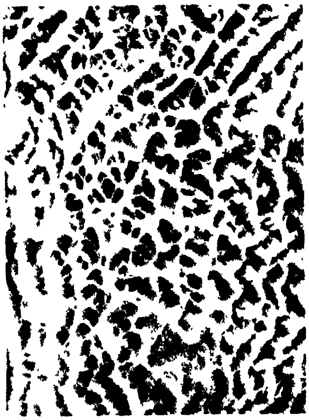

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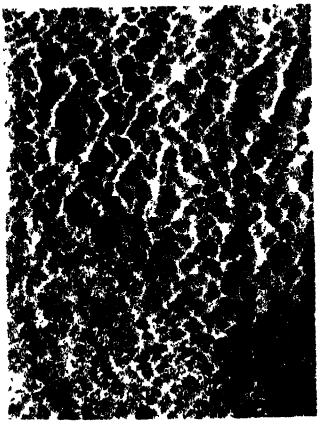

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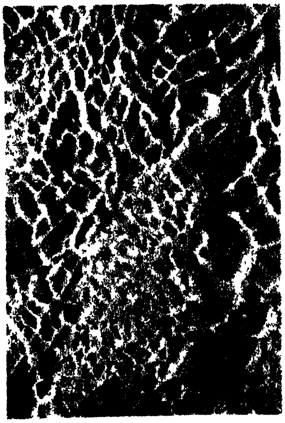

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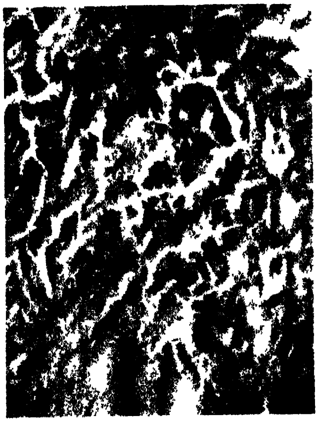

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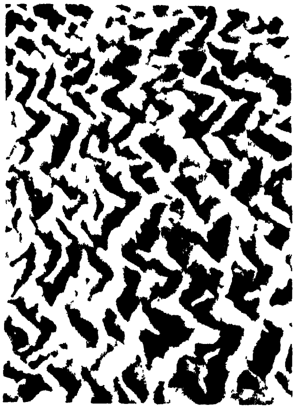

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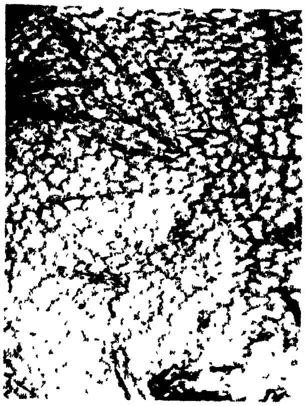

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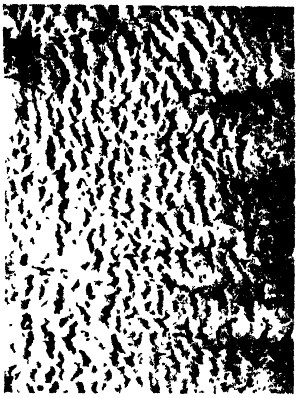

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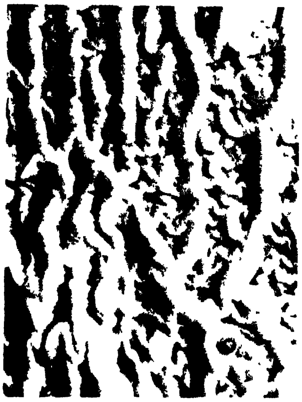

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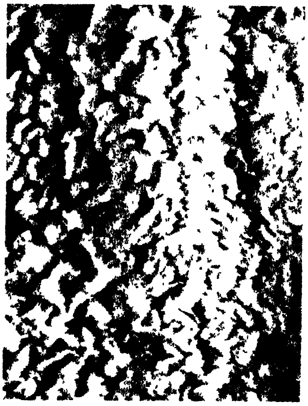

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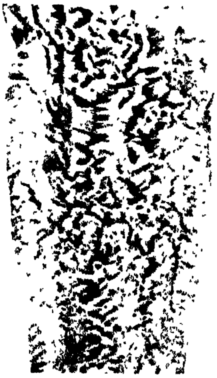

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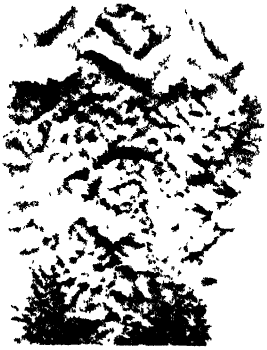

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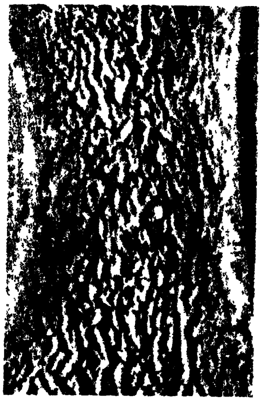

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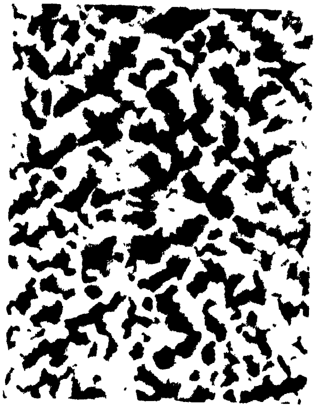

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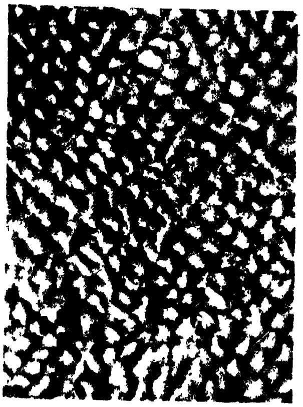

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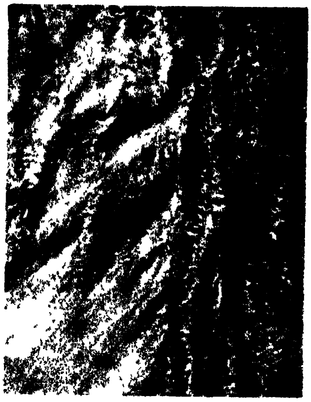

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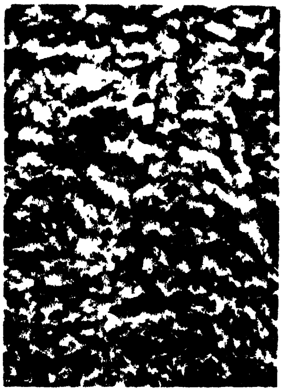

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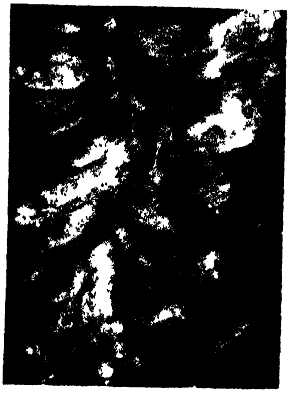

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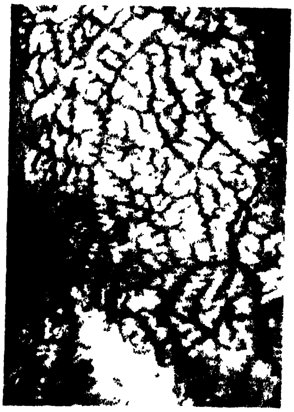

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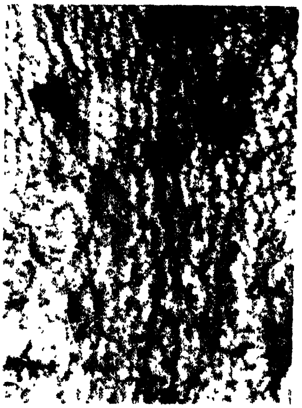

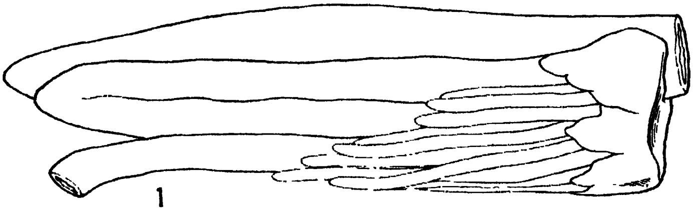

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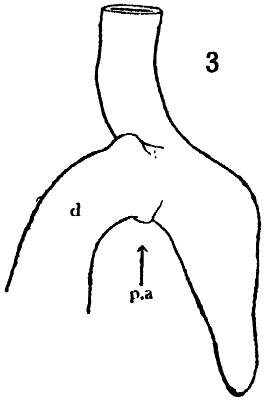

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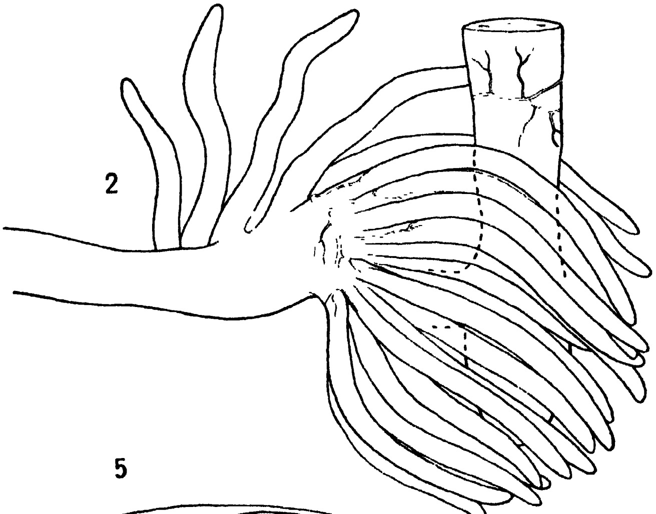

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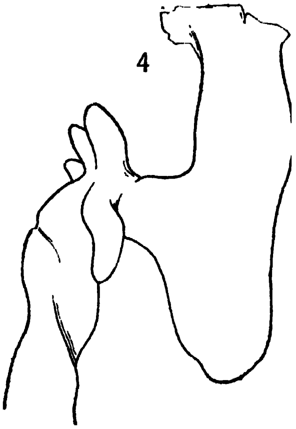

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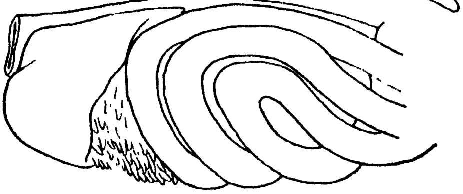

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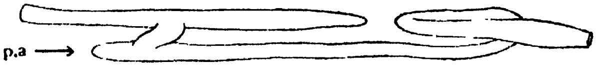

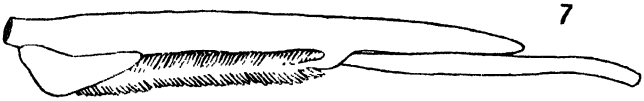

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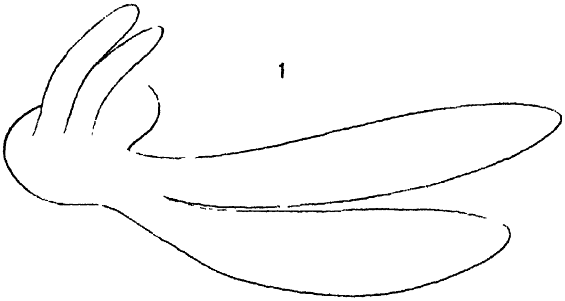

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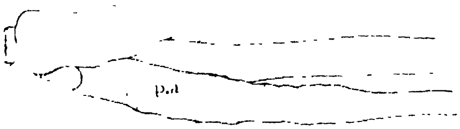

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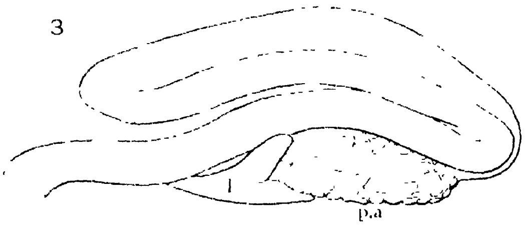

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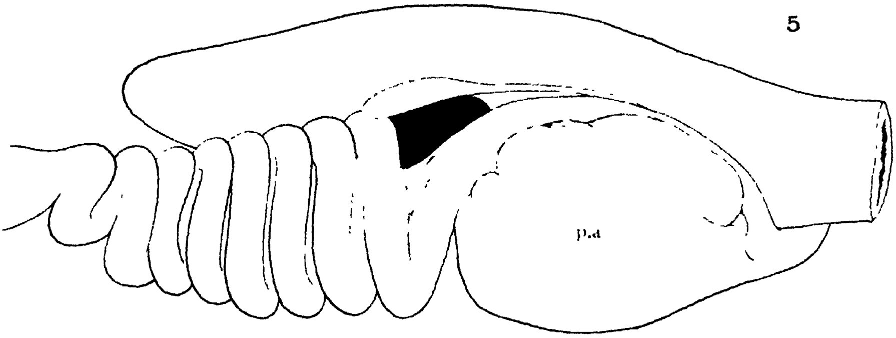

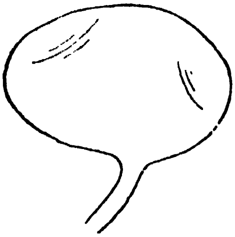

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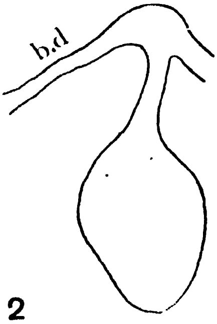

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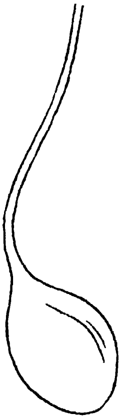

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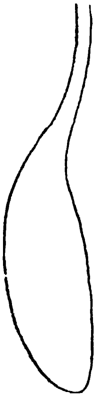

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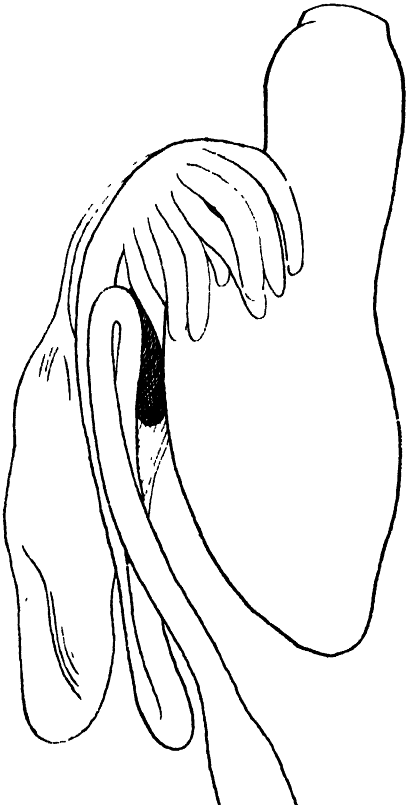

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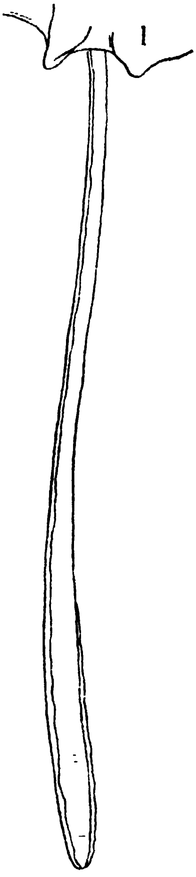

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2. Reproduction, Development and Rearing of *Penaeus Japonicus* Bate

By Motosaku HUDINAGA

Research Institute of Nippon Suisan Kaisya Ltd., Tokyo

(With 38 Figures, 36 Tables and Plates XVI-XLVI)

(Received November 30, 1941)

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Introduction

The prawn, *Penaeus japonicus,* being one of the most important crustaceans from fisheries' point of view in Japan, has been studied by some scholars in our country. The pond-culture of it has recently developed as a profitable industry and its future scope is quite promissing. Thus, the need of further study of the prawn is increasing.

In June 1934, the writer succeeded to let the parent prawns to spawn in the laboratory, and reared their larvae throughout the metamorphosis from hatching to the mysis stage. Since then he has devoted himself to the study of the prawn, the main object of his efforts being to obtain the best method of artificial and large-scale culture of it. During the two years, 1934 and 1935, the experiments were carried out on the coast of Amakusa, Kyusyu, and later in the Inland Sea on the coast of Yamaguti Prefecture.

As previously stated (1935), this prawn is hardy and its larvae in their nauplius stage are not difficult to keep alive, but upon reaching the zoea stage they become weak and numbers of them die. As the result only a few larvae attain the mysis stage passing through the zoea. The larvae in the mysis stage, however, are much stronger than in the zoea stage and can easily be kept alive for a long time. After the mysis stage the post larvae become much more stronger rendering their handling much easier and simpler. Therefore, in the culture of this prawn, and especially to raise wanted number of the young the most important matter is to rear them successfully in the zoea stage.

In the summer of 1938, the writer succeeded for the first time in rearing a rather large number to pass safely into mysis, and in the summer of 1939 he obtained better results than in the preceding year. He repeated the experiments in the summer of 1940, and at this time a considerable number of larvae metamorphosed into mysis, from which they grew further, as just stated into post larvae and eventually attained the adult prawns. The larvae that hatched from the eggs in June 1940 grew by the rearing in October of the same year as large as from 8 to 10 cm in body length, thus large enough for disposal in the market.

Concurrently with the studies in the artificial culture of the prawn the writer studied the copulation, spawning habits, fertilization, etc., in continuation of the work already published in 1935. In the present paper experimental studies since 1935 regarding the reproduction, the development and the methods of rearing the larvae and the culture of post larval stage are described.

Recently, two reports on the study of Peneidae were published, the one by Pearson (1939) and the other by Heldt (1939). The former deals with six species found on the coast of the Bay of Mexico in the Atlantic Ocean, and the latter five species found on the coast of Tunis in the Mediterranean Sea. The writer will not dwell here on the history of the study of Peneidae, which was begun by Muller (1863) and Claus (1876), as it was fully reviewed by Heldt (1939).

Before proceeding further, the writer wishes to record here his great indebtedness to Prof. Ikusaku Amemiya of the Tokyo Imperial University, who gave constant guidance and good advice and also has kindly read over the manuscript. He is also much grateful to the Director of our Laboratory Mr. Hirosi Nagatomo and Mr. Tosio Kumada, both of whose encouragement and valuable suggestion for the study were incalculable. Thanks are also due to Assistant Prof. Yosiyuki Matue for the culture method of diatoms which were used for food of larvae in their rearing and also to Assistant Prof. Yasuo Ohsima for many valuable informations. Finally, the writer expresses his gratitude to Messrs. Masao Kondo, Asakiti Yamaoka, Kasio Ohta, Haruhiko Iriye, Noboru Kasahara, Zennojyo Osio and Kazuo Obana, all of whom gave kind assistance for the study.

I. Material and Method

The laboratory is situated at the prawn fishing center of the Inland Sea, the fishing grounds being from two to five miles off the coast. To secure the spawning prawns was a simple matter as we could obtain them directly from the fishermen on the spot by rowing out to the fishing ground every morning

The research material, consisting of eggs and larvae, were all reared in the laboratory, those obtained out at sea being used merely for comparing them with those artificially reared.

In order to know the number of exuviation exactly each material was kept in a separate jar.

For fixing the ovary, Bouin's solution was used, and for staining haematoxylin and eosin method gave good result.

The method of rearing the larva at each stage of its life cycle will be described as we proceed.

II. Reproduction

i. *Copulatory Organs*

The copulatory organs of *P. japonicus* are petasma in the case of the male, and thelycum in that of the female. These organs have attracted the attention of zoologists from sometime past. Bate (1888) and Kishinouye (1896, 1898, 1900) published detailed reports of them. Although regarding the subject of petasma nothing further more is necessary, there is still some room for studies of the thelycum.

Although Kishinouye (1898) noted the presence of spermatophores in thelycum, the writer could not confirm it. As will be seen from Pl. XVI. Fig. A, the thelycum of this prawn may appear to a casual observer as having only a single wall something like a sack. Upon removing the ventral wall, however, it is found that the dorsal wall of the thelycum is not simple, but divided into two lateral halves and joined in the middle line. Besides, as shown in Pl. XVI, Fig. B. there is a hole in the dorsal wall of the thelycum. And the real seminal receptacle is a small depression in the body wall behind the thelycum (Pl. XVI, Fig. C). This receptacle is a blind cavity possessing a very thin membrane, a part of which is the dorsal wall of the thelycum said just above. This cavity can be clearly made out after a female has received spermatophores from a male by copulation. Plate XVII, Fig. A shows the stopper inserted deep into the thelycum, and Fig. B reveals that the spermatophores joined to the lower end of the stopper are not in the thelycum, but in the cavity, as viewed laterally. Fig. C shows the cavity containing spermatophores as viewed from the ventral side.

ii. *Mating Habits*

Very few writings on the copulation of Peneidae could be found. Palombi's report (1939) on the same subject in connection with *Eusicyonia carinata* is the only one that the writer is aware of. For observing the mating habits of this prawn in the summer of 1940 a concrete tank, 18 × 18 × 1 m, was prepared in the breeding-pond. An opening was made in the tank to enable the seawater to flow freely in and out of it according to the tides. Twenty pairs of fully grown prawns, from 18 to 20 cm, were placed in the tank. Observations were continuously made every night, the writer standing in the middle of the tank. Since the prawns hide themselves in the sand and rarely come out during the day, naturally copulation does not take place in the daytime. They prefer to hide themselves underneath the sand, should artificial light be too bright, thus necessitating a weak flash-light in order to observe its mating habits in the night. During a period of two months from the middle of July to the middle of September the writer succeeded in witnessing copulation five times. The details are as follows.

The five copulations observed all occurred between the hours of from 0 a. m. to 3 a. m. Copulation was not able to be observed at any other time.

Copulation, as usually seen among other crustaceans, occurs between a hard male and a soft female, that is to say, it is performed soon after the female's exuviation, previous to which the male follows the female. During this period they do not swim about, but creep about at the bottom of the water. When the male is following the female it appears as if the former catches hold of the latter's telson by means of its chelae. The time spent in the pursuit was difficult to record, as observation was possible only sometime after the pursuit had begun, and so far as in the accessible cases the longest was 7 minutes and the shortest 3 minutes. The writer never saw more than one male followed a female; always one male pursued one female. Once the pursuit begins, the dim light of the flash-light does not disturb them from copulation. The female exuviates while being pursued by the male. At the instant of exuviating, the female lays her body sideways and jumps about in the water, bending her body ventrad, when the male advances to the side of the female and embraces her on her ventral side. The pair, by keeping their ventral sides attached, swim with their bodies inclined. Plate XVIII, Figs. 2 and 3 are pictures of the pair as they were taken out of the sea-water and placed in the posture of the copulatory act. Fig. 2 shows the pursuit and Fig. 3 the process of copulation. The time required for copulation is usually 3 or 4 minutes. It is believed that during the time the pair are embracing each other, while the male by means of the petasma ejects the spermatophores protruded from the bases of the 5th pereiopods of the male. Spermatophores reach the seminal receptacle through the thelycum. According to Palombi (1939), a male *Eusicyonia carinata* behaves previous to copulation in such manner as to sexually stimulate a female. Such intricate behaviour, so to speak the courtship, however, could not be observed in the case of *P. japonicus*. After Palombi in the case of *Eusicyonia carinata*, the male is not satisfied with a single copulation; some of them copulate with as many as from 15 to 20 females in succession. On the other hand, the male of *P. japonicus* is unable to copulate twice in the same night, because the spermatophores it possessed have already been deposited in the one female.

After copulation male and female separate taking no further notice of each other. According to Herrick's observations (1911) in the American lobster, the pair continues to share the same hiding-place after having once copulated. From Ohsima's observation (1938) on *Portunus trituberculatus*, the male of the crab continues to protect the female until the latter's soft shell hardens following copulation, which, however, is not the case with *P. japonicus*.

According to the report of Ohsima (1938) the females of *Portunus trituberculatus* after having once copulated usually do not repeat the act until next spawning, keeping the spermatophores for a long while in the seminal receptacles for the next spawning season. In the case of *P japonicus*, however, with repeated moults during the summer-time, the females cast off the old shells together with the spermatophores at each moult, and the soft females receive new spermatophores from the males by each copulation. Plate XIX, Figs. 5 and 6 show an old shell to which a stopper and spermatophores adhere. The writer bred a female and a male that had copulated in the concrete tank in order to ascertain whether or not the old shell is shed with the stopper and spermatophores at every moult. The female that moulted and copulated on August 2, 1910, again moulted and copulated on August 22. The same female moulted and copulated for the third time on September 15, on which occasion the writer observed that the stopper and the spermatophores were cast again with the old shell. Similar experiments with other prawns on several occasions gave the same result. Thus, it goes without saying that in each moulting the old shell is shed and thrown away together with the stopper and the spermatophores.

A question that arose in the writer's mind was, how are these things actually performed in the open sea? Copulation in an artificial tank in which the prawns are bred is easily performed as there is a male in the vicinity when a female moults, but at the bottom of the open sea it may not always be possible for the partners to be within reach of each other. Naturally there may be cases where a female might moult and not copulate. In order to answer this question, he proceeded to a fishing ground in August, 1910, and collected soft-shelled females from the fishermen and examined them. The result was that, out of 1 124 soft-shelled females there were only 7 that had not copulated, that is, those that had not copulated did not exceed 0.5% of the total. From this result it is possible to say that copulation takes place after each moult in the open sea as elsewhere.

iii. *Ovarian Egg*

By sectioning an immature ovary it is found that the egg is covered with a layer of follicle-cells, and that there are 2 or 3 nucleoli (Fig. 1, A; Pl. XIX, Fig. 1). An example of crustacean eggs covered with follicle-cells is described in the report of Ishikawa (1885) on *Atyephira compressa*, while Herrick (1911) has made a similar statement regarding the American lobster. The difference between those eggs and that of *P. japonicus* lies in the fact that the egg of the latter has no real vitelline membrane. The egg grows gradually by absorbing the follicle-cells, as a consequence of which they become smaller (Fig.

1, B; Pl. XIX, Fig. 2). It was found on sectioning a fully matured ovary that the follicle-cells are almost absorbed by the egg, now looking like a thin membrane, while the nucleoli become still smaller and their number increases (Fig. 1, C; Pl. XIX, Fig. 3). According to Herrick in the American lobster, the follicle-cells after being absorbed become a cortical layer. In *P. japonicus* it can scarcely be called a cortical layer, for when the egg is extruded in the sea water, it is not covered by this cortical layer but is naked.

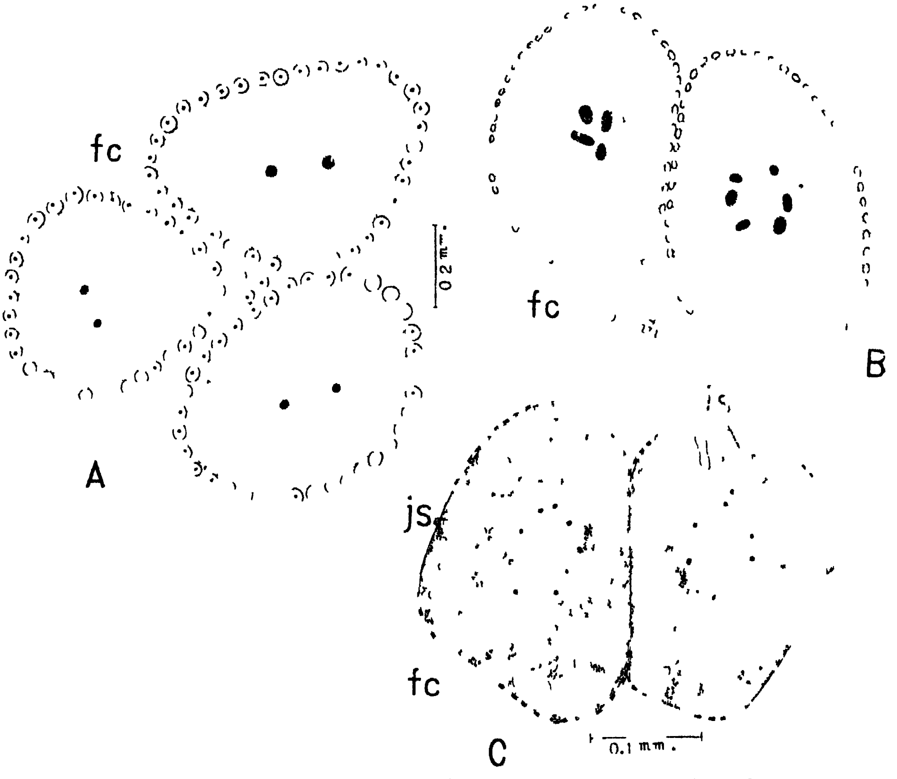

Fig 1. Section through ovarian egg A Young ovarian egg; B. Slightly developed ovarian egg, C Almost ripen ovarian egg. *fc*, follicle cell; *js*, jelly like substance

When the follicle-cells have almost been absorbed, certain substance is formed in the cytoplasm near the surface within the egg (Fig. 1, C; Pl. XIX, Fig. 3). This substance which stains with eosin is unaffected by haematoxylin. As soon as the egg is laid in the sea-water, it secretes egg-jelly around it and the said substance disappears, whence it is conceivable that the jelly-like substance is present condensed in the interior of the egg. Although the existence of this substance cannot be known upon crushing the egg on the slide-glass before the melting of the germinal vesicle, it can be seen after its melting prior to the extrusion of the egg (Pl. XIX, Fig. 4). This explains the fact that the substance, which is liquid in the beginning, changes into a semi-solid with the melting of the germinal vesicle; in other words, there occurs a change in its nature.

Something resembling this substance is found in the polyclad egg. According to Kato (1940) in regard to the polyclad egg, numerous granules appear in the cytoplasm of an ovarian egg after the germinal vesicle has melted. Eosin stains this granule. The granules which form one or two layers move close to the surface in the uterine egg and grow dense near the surface. When the spawning time approaches and the eggs pass through the vagina, these minute granules cohere and form a layer. This layer, which separates from the egg soon after it is spawned, expands by mixing with the water and changes into an egg-shell.

iv. *Oviposition*

The spawning season along the coast of Yamaguti Prefecture of the Inland Sea begins at about the middle of May and lasts till the end of September. The high season is between the middle of June and the end of August We find, however, that during from the middle of April to October some of the females have well-matured ovaries. It is difficult to obtain matured prawns during the rainy season in Japan, that is, from the middle of June to the first 10 days of July, as few fishermen then go out fishing. Although the number of females possessing full-grown ovaries is comparatively smaller in September than in July and August, there are more opportunities of obtaining those with matured ovaries in September, which is the busiest season for prawn fishing.

Table 1

Spawning time

Time	June			July			August			September			Total
	First decade	Middle decade	Last decade	First decade	Middle decade	Last decade	First decade	Middle decade	Last decade	First decade	Middle decade	Last decade	
8 10 p m.	5	7	10	8	1	1	1	0	0	1	0	0	34
10–12 ,,	2	8	8	10	8	1	2	1	2	2	2	1	50
0 2 a. m	1	2	3	5	16	16	25	22	21	21	20	13	165
2 1 ,,	0	0	0	1	12	14	19	18	16	17	23	8	128
4–6 ,,	0	0	0	0	3	4	7	3	6	5	6	2	36
Total	8	17	21	24	40	39	54	14	45	46	51	24	413

Spawning takes place at night. The writer's experiments in recording the time of spawning were carried out with 413 prawns during the years 1939 and 1940 The result (see Table 1) shows that, during June and the first decade of July, the majority spawned in the hours from 8 p. m. to 12 p. m., and that they rarely spawned after midnight. A great number of them spawned between midnight and 4 a m, rarely doing so before midnight after the middle decade of July. According to Heldt (1939), *P. trisulcatus* spawns between 8 30 p m. and 10 30 p. m

The prawns spawn while swimming very leisurely in the water (Fig 2). Under ordinary conditions, they never spawn at the bottom of the sea. On observing their spawning positions in a breeding-pond about 3 feet deep, it is found that they spawned usually at a distance of 1 or 2 feet from the bottom of the water and sometimes they approach close to the surface. On occasions in which they are spawning, they slightly bend down the body part posterior to the 4th abdominal segment, then 5 pairs of pereiopods being tightly held to the body and vigorously moving their 5 pairs of pleopods forward and backward, while quietly moving the tips of the last 3 pairs of pereiopods left and right Owing to the tiny whirlpools set up around the pleopods by the forward movement of the body and the action of the pleopods, the flow of the spawned eggs, which are divided into right and left between the 1st and the 3rd pairs of pleopods, are scattered behind and gradually sink to the bottom of the water, but as the eggs are only slightly heavier than sea water, even a slight movement of the water hinders their sinking

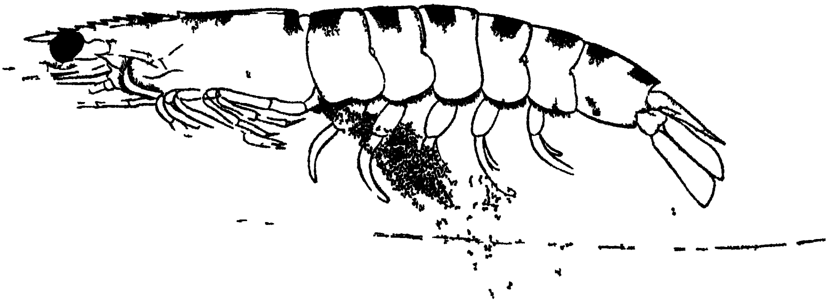

Fig 2 Spawning posture as it swims

Before spawning, the prawns stay quietly on the bottom of the water, but when the time of spawning approaches, they behave as if they were suffering from something by laying their bodies sidewise or by bending the rear part of the abdomen although not all prawns behave in the similar manner. In the beginning of the act the eggs merely ooze out, but they soon afterward gush out. The time required for one spawning is 3 or 4 minutes The number of eggs spawned differ with the size of the prawns, being approximately 700,000 by a prawn 20 cm long. Heldt reported (1939) that the number of eggs of *P. trisulcatus* is 800,000 when the spawning is 'incomplete, but from

1,000,000 to 1,200,000 when it is complete.

If a prawn is touched with a pointed object in the midst of spawning, it sinks to the bottom of the water while still continuing to spawn. At the bottom it keeps moving its 5 pairs of pleopods, the spawned eggs being scattered at the 1st pair of pleopods as the result of the movement of the pleopods. If the prawn be touched again, it sometimes stops moving of its pleopods, although still spawning. When the pleopods stop moving, the spawned eggs, instead of being scattered in all directions, are piled up below the spawning aperture, which condition disfigures the shape of the eggs. There is no doubt that these groups of eggs do not hatch, whence comes the conclusion that in the spawning of this prawn it is of the utmost importance that the eggs shall be scattered in all directions and not be allowed to pile up in heaps.

As already described, *P. japonicus*, when it begins to spawn, continues to do so notwithstanding minor, external stimulation, although if the stimulation is too strong, it sometimes stops spawning, in which case the prawn may descend to the bottom where, after an interval of 2 or 3 minutes, it resumes spawning. There are two ways of spawning in the latter case; spawning while swimming about and spawning at the bottom by the prawn's merely moving its pleopods. Should there happen to be the Japanese killifish (*Oryzias latipes*) or a small goby in the vicinity of a spawning prawn in the breeding-pond, the discharged eggs are devoured by these fishes.

When completing their spawning, the prawns rest at the bottom of the water and take food that is offered to them; they even eat their own eggs if they discover any of them about. The act of spawning does not seem to weaken the prawns. Although in this statement the writer agrees with Heldt (1939), but disagrees with the views of Weymouth, Lindner and Anderson (1932), who all believe that *P. setiferus* dies immediately after spawning. What they probably mean by immediate death may not be that the animals die immediately after spawning, but that they do so sometime following the spawning. If the latter is the case, it is not difficult to prove it by pointing to another prawn as the example, *P. orientaris*, so abundant in the Yellow Sea and in the Pechili Gulf. In the prawn various facts seem to show that it does die sometime after the spawning.

According to Heldt (1939), *P. trisulcatus* spawns at the bottom of the water with its body bent at an angle of about 120 degrees and by moving only their 3 pairs of pereiopods, but from the writer's actual observations as described above, it is unusual for *P. japonicus* to spawn at the bottom of the water. Even if they do so, they vigorously move their pleopods and scatter the eggs, causing at the same time small whirlpools around their bodies; otherwise the eggs would be disfigured and would not hatch. Besides *P. japonicus*, the writer has observed the spawning habits of *Penaeopsis monoceros* and of *Penaeopsis affinis*, and has found that both of them spawn while swimming about in the water or vigorously moving their pleopods when spawning at the bottom of the water, or else their spawned eggs will not hatch.

v. *The Egg immediately after Extrusion*

The egg, which at the instant of extrusion is of an irregular sphere or oval form (Pl. XX, Fig. 1), immediately discharges radially the whitish, translucent, jelly-like substance from within, as already described (Pl. XX, Fig. 2). Later, this substance separates from the egg (Pl. XX, Fig. 3), after which it becomes elongated, but with secretion of egg-jelly around the egg it gradually becomes smaller and forms granules (Pl. XX, Figs. 4, 5 and 6). The granules retreat from the egg-surface gradually as far as the distance exceeds the diameter of the egg. At a water-temperature of 27°C, the granules disappear about 7 minutes after spawning. The egg is, however, found to be covered with egg-jelly when the granules have disappeared. Being transparent the egg-jelly can be seen only by dropping ink on it. The transparent egg-jelly, which still remains after formation of the fertilization membrane, disappears sometime before the first segmentation begins. In rare cases it still remains even after the first segmentation has completed. The writer found that the eggs of *P. monoceros* also discharge similar jelly-like substance immediately after spawning as in the case of the eggs of *P. japonicus.*

Although as already stated, the eggs assume an irregular form the moment they have extruded, they gradually become spherical when all the jelly-like substance has been discharged (Pl. XX, Figs. 1, 2, 3, 4 and 5); they become spherical 1.5 or 2 minutes after spawning. The size of the egg immediately after spawning is very large, because it contains the jelly-like substance, after discharge of which the size of the egg diminishes. Picking up 20 eggs of comparatively regular form immediately after spawning and before discharge of the jelly-like substance, the average of the long axis was found to be 0.32 mm and that of the short axis 0.29 mm, and its volume 0.011 mm^3. The average diameter of 20 eggs that had become spherical after discharge of the jelly-like substance was found to be 0.24 mm and the volume 0.007 mm^3, which is a reduction of 50 percent. The volume reduced equals that of the jelly-like substance retained in the egg.

vi. *Fertilization*

When the ovary is fully matured and as soon as the germinal vesicle of the egg within the ovary melts, spawning begins. At the time of spawning the spermatozoa within the spermatophore which is in the seminal receptacle, are discharged into the sea-water through a pair of very tiny apertures located at the base of the 4th pereiopods of the female (Fig. 3).

The structure of the spermatozoon is quite simple consisting of a head which is the main part and a short tail that is attached to it (Fig. 4). The diameter of the head is 5.0–5.3 μ, which is equal to the length of the tail.

The apertures of receptacle through which the spermatozoa pass are so small that it is impossible to see them with the naked eyes. In order to locate these apertures, the writer used a micropipette, and after satisfying himself that spermatozoa had been sucked into the pipette, he probed about with a microneedle in order to locate the minute apertures.

As the eggs are discharged at the bases of the 3rd pereiopods and the spermatozoa are discharged from somewhat below the bases of the 4th pereiopods, the two come into contact with each other as soon as they are discharged in the sea water.

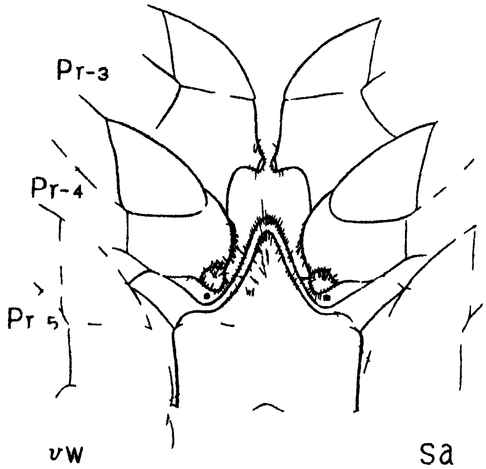

Fig. 3. Thelycum, upper half cut away, ventral view. *Pr-3*, *Pr-4* and *Pr-5*, 3rd, 4th and 5th pereiopods; *sa*, small aperture through which spermatozoa issue; *vw*, ventral wall.

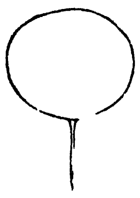

Fig. 4. Spermatozoon

Under the microscope, an egg just spawned shows that the spermatozoa have not yet reached the surface of the egg remaining around the jelly-like substance extruded by it. ,When the jelly-like substance has separated from the egg, the spermatozoa reach the egg surface within less than 1 minute after spawning. Since a spermatozoon must penetrate the layer of jelly-like substance before it can reach the egg-surface, not many spermatozoa succeed in doing so. For more than 10 of them to reach the surface of one egg is a rarity. Most of the spermatozoa remain outside the jelly-like substance that surrounds the egg. According to Chambers (1923) on fertilization of the starfish, as soon as the spermatozoa reach the egg-jelly there appear some fertilization cones at the corresponding spots on the egg-surface, from the tops of which fine fibres extend, and on reaching the spermatozoa they draw them in. The writer could not observe any phenomenon of the kind in *P. japonicus*. An entrance cone appears at the spot that comes into contact with the spermatozoon within 1.5 or 2 minutes after the spermatozoon reaches the egg. The number of these entrance cones corresponds with the number of spermatozoa which the egg-surface comes in contact with; that is to say, 3 cones for 3 spermatozoa and 4 cones for 1 spermatozoa (Pl. XXI). Sometimes the writer witnessed as many as 10 entrance cones appeared on a single egg.

In order to simplify the matters, the writer will take the case in which 2 spermatozoa reached the egg-surface, and describe the way in which these spermatozoa entered the egg. The moment that 2 entrance cones begin to protrude from the egg-surface, 2 spermatozoa which were on the egg-surface leave the egg-surface staying on the tip of the entrance cones (Pl. XXII, Figs. A and B). As they continue to protrude, the entrance cones assume a cylindrical form (Pl. XXII, Fig. C). The cytoplasm enters these cylindrical entrance cones from below. The lower half of the cylindrical cones slightly bulge owing to intrusion of cytoplasm (Pl. XXII, Fig. D). The cytoplasm that has entered an entrance cone, gradually goes up as far as the head of a spermatozoon (Pl. XXII, Fig. D). This upward movement of the cytoplasm in the two different entrance cones never occurs at the same time, one always reaching the head of a spermatozoon ahead of the other (Pl. XXII, Fig. D). The cytoplasm in the latter cone then stops its upward movement and suddenly withdraws down to the surface of the egg (Pl. XXII, Fig. E). The two entrance cones then begin to shrink. The size of the entrance cone in which the cytoplasm reached the head of the spermatozoon does not change, but the cytoplasm that is in contact with the head of the spermatozoon gradually shrinks, when one-half the head of the spermatozoon is then already inside the entrance cone. When the spermatozoon approaches the egg-surface, the cytoplasm draws the spermatozoon, as if sucking it into the egg (Pl. XXII, Figs. F, G and H.) and the spermatozoon goes in, tail and all. Since the color of the egg is dark brown, it is difficult to see the movement of the spermatozoon within the egg. At the same time the entrance cone in which the cytoplasm has not reached the spermatozoon begins to shrink until it is much smaller than the spermatozoon, after which it finally disappears leaving the spermatozoon adhering to the egg-surface (Pl. XXII, Fig. H).

The phenomenon described above is the same whether there are 3 or more spermatozoa. The cytoplasm always reaches the head of the spermatozoon in one entrance cone ahead of the others and drawing the spermatozoon into the egg and leaves the other spermatozoa only adhering to the egg-surface. The recorded time between the beginning of the protrusion of an entrance cone and its disappearance is 2 or 3 minutes.

According to the writer's observations on fertilization in *P. monoceros* and *P. affinis*, the number of entrance cones equals that of the spermatozoa that have reached the egg-surface in each instance with only one of the spermatozoon entering the egg as in *P. japonicus*. The difference between *P. japonicus* and the other two species just mentioned is that in the case of the last-named the spermatozoa entered each of the entrance cones and the cytoplasm reached the head of one spermatozoon ahead of the others, while the cytoplasm that was on its way to enter the other entrance cones instantly withdrew. The cytoplasm that has reached the spermatozoon retreats into the egg together with the spermatozoon, as if sucking it in. The entrance cone, however, does not disappear, but separates from the egg surface the moment the spermatozoon enters the egg. The other entrance cones together with the spermatozoa also separate from the egg-surface. It may be said in conclusion that should one spermatozoon succeed in entering the egg, the remaining spermatozoa are cast off from the egg-surface, entrance cones and all.

vii. *Maturation Division*

Owing to the dark-brown colour of the egg it is impossible to observe under the microscope the karyokinesis that occurs at the time of maturation division. The writer will now describe the formation of polar bodies that appear on the egg-surface.

The 1st polar body begins to appear about 4 or 4.5 minutes after spawning, completely emerging from the egg-surface within 1 or 1.25 minutes. As a consequence the time when the spermatozoon enters the egg and that when the 1st polar body appears on the egg-surface almost coincide. In other words, the two change places. Although the spot on the egg-surface whence the 1st polar body appears is somewhat flat, it however resumes its former shape after the 1st polar body has completely appeared. Often the 1st polar body that appears on the egg-surface tries to leave the egg-surface, but fails in its attempt and drops on the egg-surface, because it is connected to the surface by the protoplasmic thread (Fig. 5, A, B and C). The 1st polar body may or may not divide into two after it has appeared.

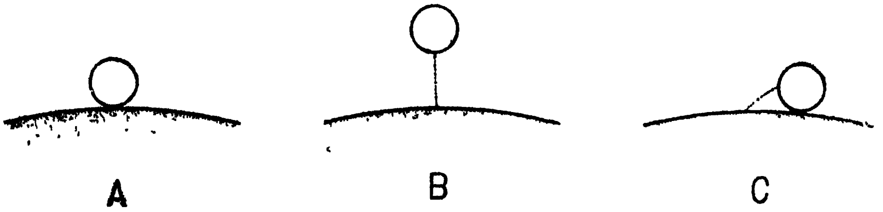

Fig 5. Diagramatic illustration of appearance of 1st polar body. A Extrusion of 1st polar body; B. 1st polar body is at a distance from egg-surface yet connected by a protoplasmic thread; C 1st polar body falls on egg-surface

As described above, since the entry into the egg of the spermatozoon and the appearance of the 1st polar body coincide, the fertilization membrane is not yet formed at the time when the 1st polar body appears, so much so that the 1st polar body appears to be present upon the naked egg-surface (Pl. XX, Fig. 6). The egg-surface, however, is actually protected by the layer of transparent egg-jelly.

The 2nd polar body appears on the egg-surface after the fertilization membrane has become elevated, that is to say, the fertilization membrane lies between the 1st and the 2nd polar bodies (Pl. XX, Fig. 7).

As the fertilization membrane elevates after the 1st polar body has appeared and before the appearance of the 2nd polar body, it is necessary to explain the formation of the fertilization membrane before describing the conditions under which the 2nd polar body appears.

The fertilization membrane elevates about 11 or 12 minutes after spawning. Chase (1935) has described a number of interesting results in connection with his studies on the formation of the fertilization membrane, his materials being Echinoderm from which, however, the formation of the fertilization membrane of *P. japonicus* differs entirely. The elevation of the fertilization membrane takes place suddenly all over the entire egg-surface. Although the fertilization membrane is perfectly spherical from the beginning, the surface of the cytoplasm is not even, because the cytoplasm of the egg does not entirely leave the fertilization membrane at one time, but remains adhering to the membrane in places (Pl. XXIII, Fig. A). Such parts of the cytoplasm as adhere to the fertilization membrane, however, leave it in the end, resulting in the cytoplasm of the egg eventually assuming a spherical shape (Pl. XXIII, Fig. B). The cytoplasm at the place where the 1st polar body is located, however, remains after the rest of it has left the fertilization membrane. Obviously, even this part later leaves the fertilization membrane but still retaining a connection to the fertilization membrane by means of the protoplasmic thread (Pl. XXIII, Fig. B, C and D). The thread probably does not join the fertilization membrane to the cytoplasm of the egg, but the 1st polar body to the cytoplasm of the egg. Even after the cytoplasm of the egg has become perfectly spherical, this protoplasmic thread is not torn, but remains intact. The fertilization membrane swells to its proper size about 3 or 3.5 minutes after it began to elevate. In 20 eggs that were examined the diameters of the fertilization membranes or egg-shells ranged from 0.26 to 0.28 mm, and that of the cytoplasms from 0.23 to 0.25 mm.

The 2nd polar body begins to appear before the fertilization membrane reaches its proper size. Since the spot from which the 2nd polar body appears is the same as that from which the 1st polar body appeared, it is exactly the same place where the cytoplasm of the egg joins the 1st polar body by means of the protoplasmic thread. The 2nd polar body appears as complete form on the surface of the cytoplasm about 30 seconds after it has started the movement, its head being joined to the 1st polar body by means of the thread (Pl. XXIII, Fig. E.). About 2 minutes after its complete appearance on the surface of the cytoplasm, the 2nd polar body begins its upward movement toward the 1st polar body through the perivitelline space, apparently drawn by the protoplasmic thread (Pl. XXIII, Fig. F). At this instant, the cytoplasm of the egg is joined to the 2nd polar body, which latter, about 1 minute after it has started its upward movement, finds itself underneath the 1st polar body with the fertilization membrane between the two (Pl. XXIII, Fig. G). The moment the 2nd polar body reaches the fertilization membrane, the thread which is found between the 2nd polar body and the cytoplasm is torn (Pl. XXIII, Fig. H).

This phenomenon is not peculiar to every egg. Sometimes the connecting thread between the 1st polar body and the cytoplasm is torn previous to the appearance of the 2nd polar body. In such cases, the 2nd polar body stops its upward movement halfway before it reaches the fertilization membrane. Or, if the perivitelline space is so narrow that the 2nd polar body can barely pass through it, naturally no upward-movement of the 2nd polar body can be expected.

P. affinis is the most suitable species for observing the upward-movement of the 2nd polar body. In this species, the perivitelline space is fairly wide enabling a clear view of the upward movement of the 2nd polar body. A similar phenomenon was observed in *P. monoceros*.

The various phenomena that precede the beginning of the 1st segmentation of an egg immediately after spawning are shown with their times in Table 2.

Table 2

Change of egg

Spawning time 0.15 a.m. VII 21, 1940.
Water temp. 27.3°C. Salinity 29.4‰.

Time elapsed after spawning min. sec.	Remarks
0	Spawning.
0 45	Spermatozoa attach to the egg-surface.
1 40	Egg becomes spherical.
2 20	Entrance cones begin to appear.
3 05	Entrance cones reach maximum size.
4 20	Entrance cones disappear.
4 10	1st polar-body begins to appear.
5 25	1st polar-body appears perfectly on the egg-surface.
7 00	Jelly-like granules disappear, but transparent egg-jelly surrounds egg-surface
11 20	Fertilization membrane begins to elevate.
14 30	Fertilization membrane reaches full size.
12 40	2nd polar-body begins to appear.
15 30	2nd polar-body attaches itself to fertilization membrane.
28 00	Egg-jelly disappears.
30 15	Zygote begins its first cleavage

III Development

i. *Embryonal Development*

Segmentation: In 1935 the writer published a detailed report on the segmentation of the egg of *P. japonicus*. Since then in studying the segmentation of the eggs of *P. monoceros* and *P. affinis* he found that it is in the two species exactly the same as that of *P. japonicus*. Heldt (1939) also reported that the segmentation of the eggs of *P. trisulcatus*, *Parapenaeus longirostris* and *Sicyonia carinata* is the same as that of *P. japonicus*, for which reason the writer will try here to describe only briefly the segmentation of the present species.

A total and equal segmentation occurs in the egg of *P. japonicus*. The 1st segmentation begins about 30 or 40 minutes after spawning at water temperature of from 27° to 29°C, the time required for the 1st segmentation being 2 or 3 minutes (Pl. XXIV, Figs. 1, 2 and 3).

The 2nd segmentation begins 12 or 15 minutes after the 1st segmentation. The characteristic of the segmentation of the egg of Peneidae is observed at the 2nd segmentation. At the beginning, the cleavage plane of the 2nd segmentation makes a right angle with the 1st cleavage plane (Pl. XXIV, Fig. 4). The two daughter cells raised by the 1st segmentation rotate in opposite direction to each other with the progress of the 2nd segmentation, and are segmented into 4 (Pl. XXIV, Figs. 5 and 6). The time required for the 2nd segmentation is 2 or 3 minutes. If two imaginary straight lines are drawn connecting the centers of the two pair cells at the end of the 2nd segmentation, the two lines would make a certain angle between them instead of being parallel. These angles, which differ with the egg, are usually from 15 to 60°, sometimes as much as 90 or no angle at all. The degree of the angle depends on the rate of rotation. Plate XXIV, Fig. 7 shows the various phases at the 4-cell stage.

The 3rd segmentation begins about 12 or 15 minutes after the 2nd, its cleavage plane making a right angle with the 2nd cleavage plane. Such complicated rotation as that observed at the 2nd segmentation is not seen any more in the segmentations that follow the 2nd, the cleavage plane that follows always making a right angle with that which preceded it. Segmentation thus progresses at intervals of 12 or 15 minutes (Pl. XXV, Figs. 1, 2, 3, 4, 5 and 6).

The vegetative pole of the embryo, which somewhat flattens, begins to invaginate about the time the number of cells has increased from 64 to 128. An embryonic membrane clearly appears surrounding the embryo within 2 or 2.5 hours after spawning.

Formation of Appendage: The lateral surface of the embryo becomes somewhat depressed, and 3 hours after spawning shady spots are seen here and there on the embryo. It is assumed that at this period a certain intricate change takes place in the interior of the embryo. The depression of the lateral surface disappears within 30 minutes and the shape of the embryo becomes oval (Pl. XXVI, Fig. 2).

4 hours after spawning, the middle part of the embryo begins to swell, the swelling gradually projecting and surrounding the embryo in a ring (Pl. XXVI, Figs. 3 and 4). The width of this swelling is not regular; the wider side is the dorsal and the narrower the ventral (Pl. XXVII, Figs. A and B). This ring structure is the root of the 2nd appendage or the 2nd antenna of the nauplius. In about 10 minutes after the projection of the root of the 2nd antenna, a cleft on the median line appears at the hind part of the embryo. This cleft gradually increases in depth (Pl. XXVI, Figs. 4 and 5).

The root of the 3rd appendage or the mandible appears below the 2nd appendage about 5 hours after spawning. This appendage is smaller than the 2nd (Pl. XXVI, Fig. 5; Pl. XXVII, Fig. C).

The root of the 1st appendage or the 1st antenna is formed above the 2nd appendage about 6 hours after spawning. This appendage also is slightly smaller than the 2nd (Pl. XXVI, Fig. 6; Pl. XXVII, Fig. D). The order in which these 3 appendages appear is therefore the 2nd, the 3rd and finally the 1st.

In about 7 hours after spawning, the cleft at the anterior part of the embryo resumes its former shape.

Small setae appear at the tips of the 3 pairs of appendages about 8 hours after spawning. A slight cleft appears also about midway along the lateral sides of the 2nd and 3rd appendages. These 2 appendages become biramous (Pl. XXVII. Figs. E and F). The clefts that have appeared on the 2nd and 3rd appendages are more distinct about 9 hours after spawning becoming complete biramous appendages about 10.5 hours after spawning (Pl. XXVII, Fig. G). Later, these appendages become gradually narrower and elongate.

Nauplius in the Egg-Membrane:- The embryo is faintly divided into 4 somites at the ventral side, and a small swelling which is to become the labrum appears near the anterior edge of the ventral side about 8 hours after spawning (Pl. XXVII, Fig. E). Later these 4 somites gradually become indistinct, when the upper half of the body which becomes larger than the lower shows a tendency to bend toward the ventral side of the body (Pl. XXVII, Figs. F, G, H and I). About 11 or 12 hours after spawning on completion of the 3 pairs of appendages the embryo progresses into a nauplius. A dark red ocellus appears about this time at the anterior end of the body, which lies slightly on its ventral side. Usually the colour of the body becomes dark or yellowish-black, when dark red and brown pigments appear around the ocellus and on that part slightly below the middle of the dorsal side. 12 or 13 hours after spawning, the nauplius in the egg-membrane begins convulsive movements from time to time at the bases of the 1st and 2nd appendages and at the projection on the dorsal side.

The nauplius in the egg-membrane emerges into the outside world by breaking the egg-membrane; this occurs about 13 or 14 hours after spawning. The embryonic membrane is broken prior to that of the egg-membrane; the nauplius with 1st and 2nd appendages dangling from the ventral side first punctures the egg-membrane by extending a pair of spines at the posterior end (Pl. XXVIII, Fig. 3); at this instant the posterior half of the body slides out and the whole body emerges by pushing up the upper part of the egg-membrane with the 1st appendage (Pl. XXVIII, Figs. 1 and 5). The time required for the emergence is 2 or 3 minutes.

ii. *Nauplius*

In about 13 or 14 hours after spawning in the water of temperature ranging from 27° to 29°C, the nauplius in the egg-shell emerges by breaking the egg-membrane. Immediately after hatching the nauplius is covered here and there with embryonic membrane, and although the appendages that dangle ventrally become convulsive from time to time, the nauplius does not swim. The setae of the appendages look like tangled threads.

After remaining in this condition for 4 or 5 minutes, it begins to swim for the first time by moving its 1st and 2nd appendages like paddles. The embryonic membrane ist cast off as soon as locomotion begins, when the setae of the appendages also straighten out. Locomotion is still fairly slow and swimming not continuous, but in about 20 or 30 minutes after hatching locomotion becomes brisk, and the creature already responds to light stimulus gathering in the direction of the light but avoiding direct sunshine.

Locomotion is accomplished by briskly moving the 3 pairs of appendages in paddling fashion, the 2nd appendages being the most effective of the 3 pairs for this with the 1st appendages ranking next. The 3rd appendages being the smallest are the weakest. In the movement, which is fairly swift, the body rolls about in zig-zag way on account of its appendages. When at rest it keeps its dorsal side down remaining in the water in a perpendicular position with its 3 pairs of appendages slanting upwards.

It moults 6 times within 36 to 37 hours after hatching at a water temperature from 27° to 29°C and passes into the zoea stage with the 6th moult. The length of the body increases with every moult. Since the number of setae of the exopodite of the 2nd appendage and that of the spines at the posterior end increase fairly regularly, it is possible to count the number of moults of the nauplius by merely observing the said two (See Table 3).

Table 3

The number of setae on exopodite of 2nd antenna and spine formula of body end in the nauplius stage

	1st nauplius	2nd nauplius	3rd nauplius	4th nauplius	5th nauplius	6th nauplius
Number of setae	5	6	7	9	10	12
Spine formula	1+1	1+1	3+3	4+4	6+6	7+7

The colour of the body, which is usually dark yellow at the time of hatching, fades with each moult turning whitish and semi-transparent when passing through the 5th moult. Compared with the body colour the 3 pairs of appendages at the time of hatching seem brighter and beautiful with reddish-brown specks on them.

Notwithstanding its repeated moults, the nauplius is quite strong without feeding. In a small container like a watch glass it thrives well requiring but little attention and can be easily reared, all of that is because it obtains its supply of energy from the yolk within its body. The yolk, which fills the body at the time it is hatched, is gradually absorbed with some remaining only in the digestive tract (Pl. XXIX). The yolk is almost absorbed before it passes into a zoea.

In rearing *P. monoceros, P. affinis* and *P. akayebi* the writer found that their nauplius were as strong as that of *P. japonicus.* Heldt (1939) and Pearson (1939) also reported that the nauplius which they reared all proved to be strong.

As already mentioned, the nauplius of *P. japonicus* moults 6 times. The writer ascertained that *P. monoceros* and *P. affinis* also moult 6 times in the nauplius stage (1941). But not all the species necessarily moult 6 times in their nauplius stage; according to Heldt and Pearson, the number of moults were found to differ in some of the species they studied (See Table 4).

Table 4

Number of moults in the nauplius stage

Species	Number of moults.	Observer.
P. japonicus	6	Hudinaga
P. monoceros	6	,,
P. affinis	6	,,
P. trisulcatus	8	Heldt
Sicyonia carinata	8	,,
P. setiferus	5	Pearson
Trachypenaeus constrictus	5	,,
Eusicyonia stimpsoni	5	,,

First Nauplius (Fig. 6; Pl. XXIX, Fig. 1): The body-length in 10 specimens that were examined ranged from 0.30 to 0.34 mm and the body-width from 0.16 to 0.18 mm. The length of the body was measured between the apical and caudal ends excluding the furcal spines, and for the width of the body, at the point of greatest width where the 2nd appendages are located.

Viewed dorsally or ventrally the body is somewhat elliptical, the anterior half being somewhat larger than the posterior. When viewed laterally the body is seen to bend slightly ventrad forming a dorsal convex.

The ocellus, which is present as a dark red spot at the anterior margin on the median ventral surface of the body, changes its colour to black after the 1st moult remaining so to as late as the beginning of the post-larva.

All the 3 pairs of appendages are still unarticulated being like sticks. The setae being simple are not plumose.

The 1st appendage is uniramous and slightly shorter than the body, with 2 long and 1 short setae at the tip, 3 setae internally and 1 externally at the sides.

The 2nd appendage, which is biramous, is slightly longer or as long as the 1st appendage. The endopodite is provided with 2 long and 1 short setae at the tip and with 2 short setae inside. The exopodite is slightly longer than the endopodite with 2 long setae at the tip and 3 long ones inside.

The 3rd appendage is biramous and much shorter than either the 1st or 2nd appendage, being slightly longer than $\frac{1}{2}$ the length of the two combined. Both endopodite and exopodite possess 3 long setae at their tips, the former being slightly longer than the latter. The number of setae of the 3rd appendage remains constant throughout the whole nauplius stage.

The labrum, which is semi-globular, protrudes conspicuously, the labrium being yet indistinct.

The length of the pair of spines at the posterior end, which exceeds $\frac{1}{3}$ the body-length, is flexed dorsally.

A very short spine on the dorsal median line falls away after the 1st moult.

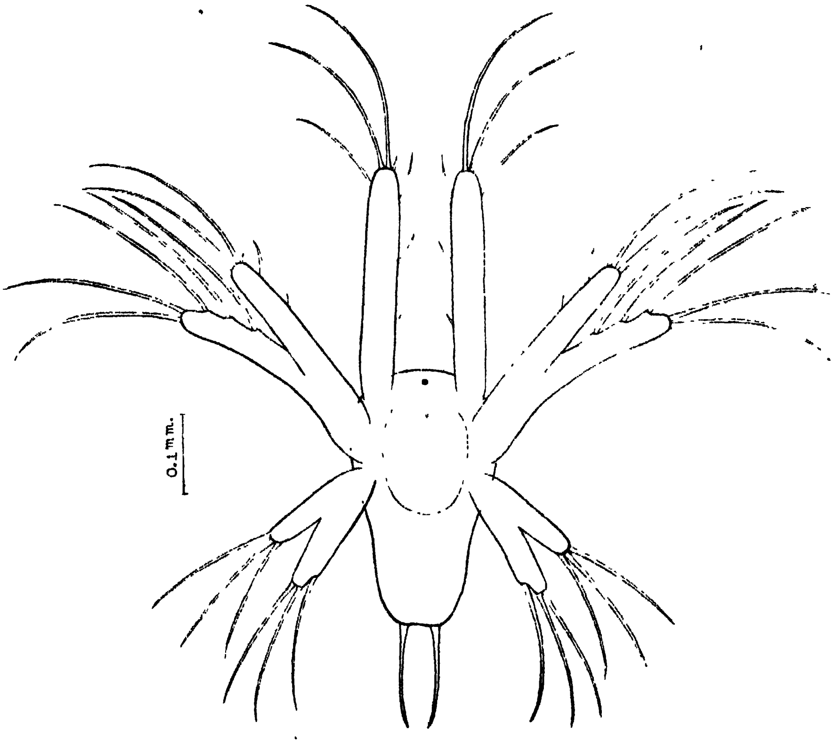

Fig. 6. 1st nauplius, ventral view.

Second Nauplius (Fig. 7; Pl. XXIX, Fig. II): — The 2nd nauplius goes through the 1st moult about 3 hours after hatching in water of temperature ranging from 27° to 29°C. In 10 specimens examined, the body-length was from 0.33 to 0.35 mm with, however, no marked change in body-width. The length of the body extends slightly in its lower half.

The outstanding difference between the 2nd nauplius and its previous substage is that most of the setae on each of the appendages become plumose.

The 1st appendage is articulated by numerous joints, which not yet being distinct are impossible to count. The number of setae is the same as that in the previous nauplius, one at the tip becomes long and plumose.

The protopodite of the 2nd appendage faintly shows 3 very indistinct joints. There is the same number of setae on the endopodite as that in the preceding nauplius, the 2 setae at the tip becoming plumose. The number of setae on the exopodite, including a very short one that has appeared at the tip totals 6. The 5 long setae that were already present in the preceding nauplius become plumose.

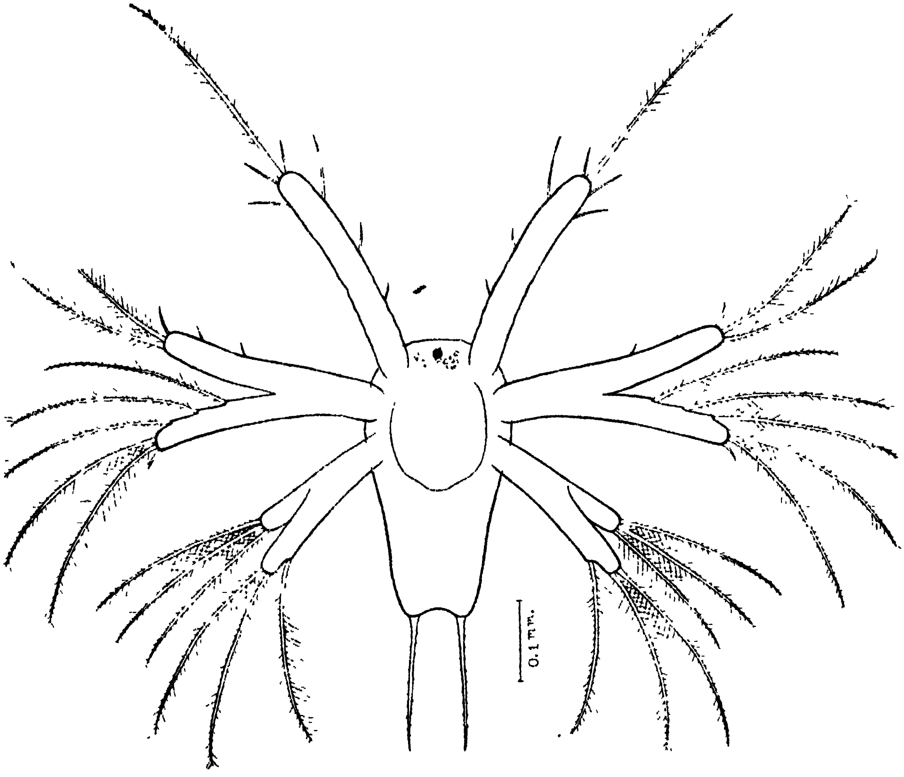

Fig. 7. 2nd nauplius, ventral view.

Compared with that of the preceding nauplius, the labrum is somewhat pointed, the labrium being rather distinctly below the labrum.

A pair of spines at the posterior end, same as that in the preceding nauplius, becomes straight lines bearing short sharp setae around it.

A pair of quite small and indistinct frontal organs appears at the anterior end of the body. They become distinct only after the 5th nauplius.

The ventral part between that part below the labrium and close to the posterior end becomes semi-transparent.

Third Nauplius (Fig. 8; Pl. XXIX, Fig. III): — The nauplius that has passed the 2nd moult advances into the 3rd nauplius about 6 hours after hatching at water temperature of from 27° to 29°C. The body-length in ten specimens was from 0.35 to 0.38 mm and the body-width from 0.17 to 0.19 mm.

A characteristic of this substage is the appearance of rudiments of 4 pairs of appendages at the ventral transparent part of the body. In other words, the anlages of the 1st maxilla, 2nd maxilla, 1st maxillipede and the 2nd maxillipede faintly make their appearance. Although the first 2 of the 4 pairs of appendages are rather distinct, the remaining 2 pairs are very indistinct being covered by a cuticle and therefore not exposed.

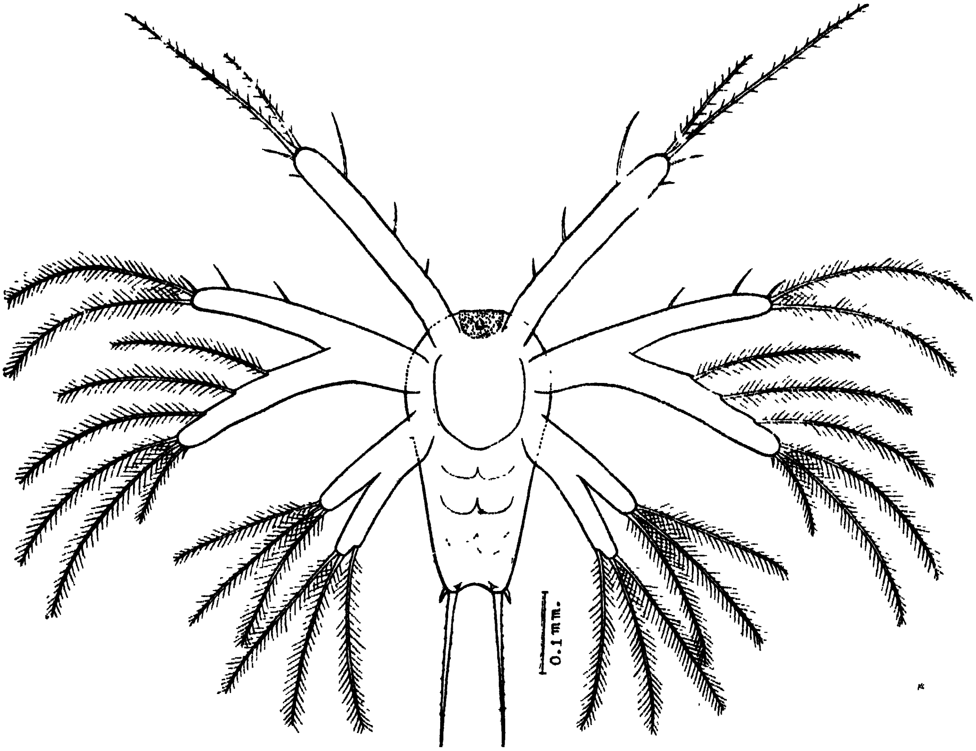

Fig. 8. 3rd nauplius, ventral view.

The setae of the 1st appendage are constant and the 2 setae at the tip plumose.

The number of setae of the endopodite of the 2nd appendage is the same as in the preceding nauplius. With the small new seta at the tip of the exopodite, the number increases to 7 and the small new seta which grew in the preceding nauplius becomes somewhat longer and plumose. Although the expodite is divided into 4 articulations, they are indistinct as in that of the protopodite.

The inner side of the protopodite of the 3rd appendage is slightly swollen and milk-white, and there the rudiment appears which later becomes the masticatory surface.

The posterior end is somewhat bifurcated. Two pairs of small spines appear anew both internally and externally. The spine formula becomes 3 + 3. The internal spines are frequently so small as to be indiscernible.

Fourth Nauplius (Fig. 9; Pl. XXIX, Fig. IV):—The nauplius after completing the 3rd moult, becomes the 4th nauplius 16 hours after hatching in water of temperature of from 27° to 29°C. In 10 specimens the body-length was from 0.38 to 0.42 mm and the body-width almost equal to that in the preceding substage.

The characteristic of this substage is that the 4 pairs of appendages that appeared in the preceding substage all become biramous and distinct. Although the endopodites of each appendage are larger than the exopodites, they are still underneath the cuticle.

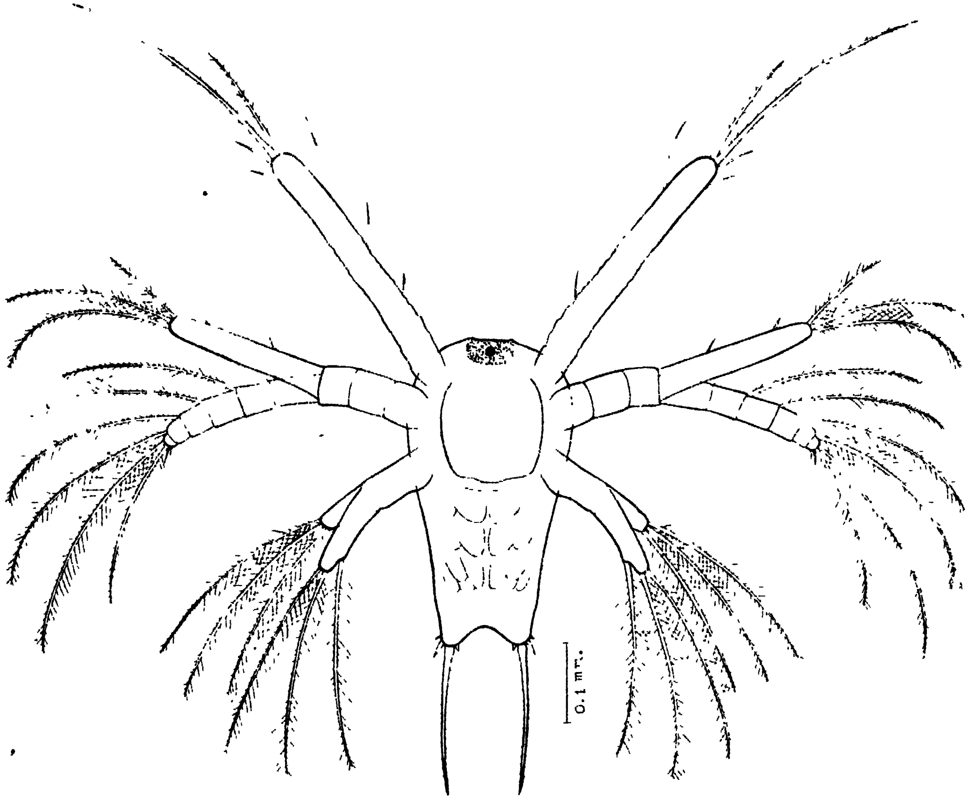

Fig. 9. 4th nauplius, ventral view.

The 1st appendage remains the same as in the preceding substage.

A small seta at the tip of the endopodite of the 2nd appendage becomes longer and plumose, the number of setae remaining unchanged. With the appearance afresh of one small seta at the tip and another small one at the side of the exopodite, their number increases to 9. Sometimes, these small setae are missing. 3 articulations of the protopodite become distinct, the exopodite having 6 articulations.

The inside of the 3rd appendage swells still further.

The spine formula becomes 4+4 with one small spine appearing anew at each outer side of the posterior end.

Fifth Nauplius (Fig. 10; Pl. XXIX, Fig. V): — The nauplius, after going through the 4th moult, becomes the 5th nauplius about 23 hours after hatching in water of temperature of from 27° to 29°C. In 10 specimens the body-length was from 0.42 to 0.45 mm and the body-width slightly larger than in the preceding substage.

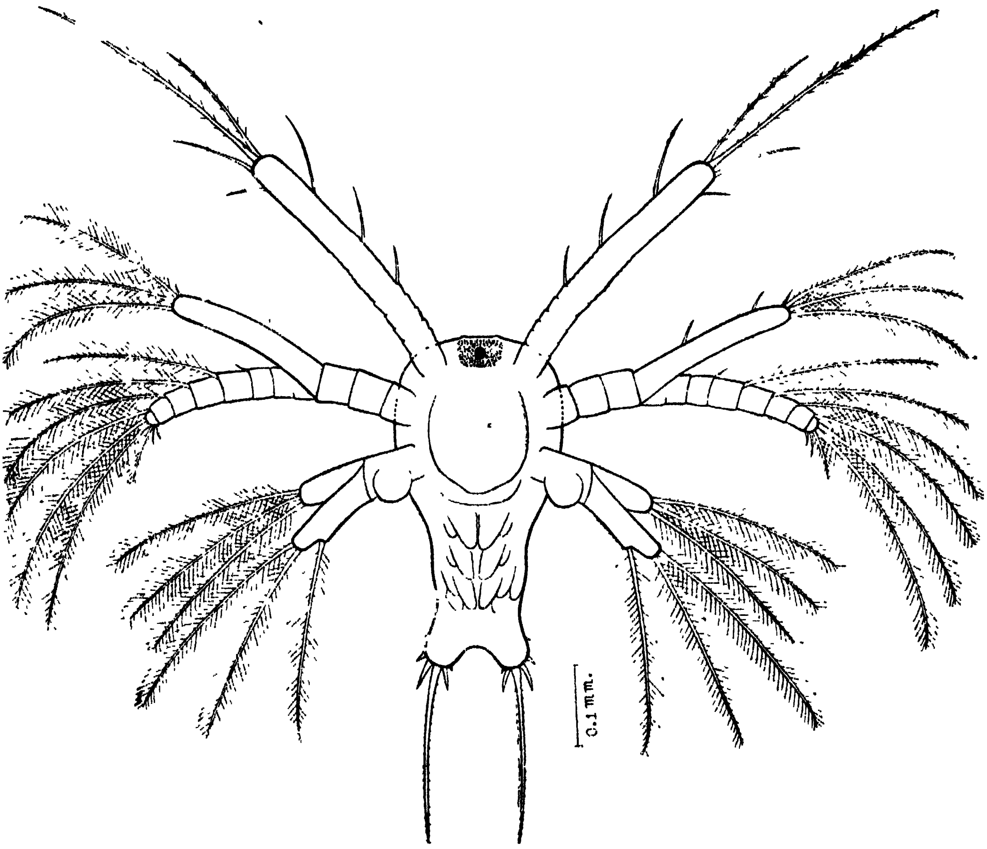

Fig. 10. 5th nauplius, ventral view.

What characterizes this substage is that the rudiment of the carapace appears somewhat below the middle of the body on the dorsal surface, the 4 pairs of appendages on the ventral side becoming more distinct.

The number of setae on the 1st appendages is constant. The articulations of the lower half of the stem become somewhat distinct.

The lengths of the plumose setae at the tip of the endopodite of the second appendage become almost equal; another small seta appears afresh. A small seta appears anew at the tip of the exopodite making the total 10 setae. Sometimes, however, this small seta is missing. This exopodite now has 8 articulations, but the 1st one is not very distinct.

The swelling inside of the 3rd appendage becomes almost spherical, and an articulation is formed between the protopodite and the branches.

Compared with the preceding substage the posterior margin extends considerably and the bifurcation at the end becomes more conspicuous. The spine formula becomes 6+6 with the addition of a spine each internally and externally.

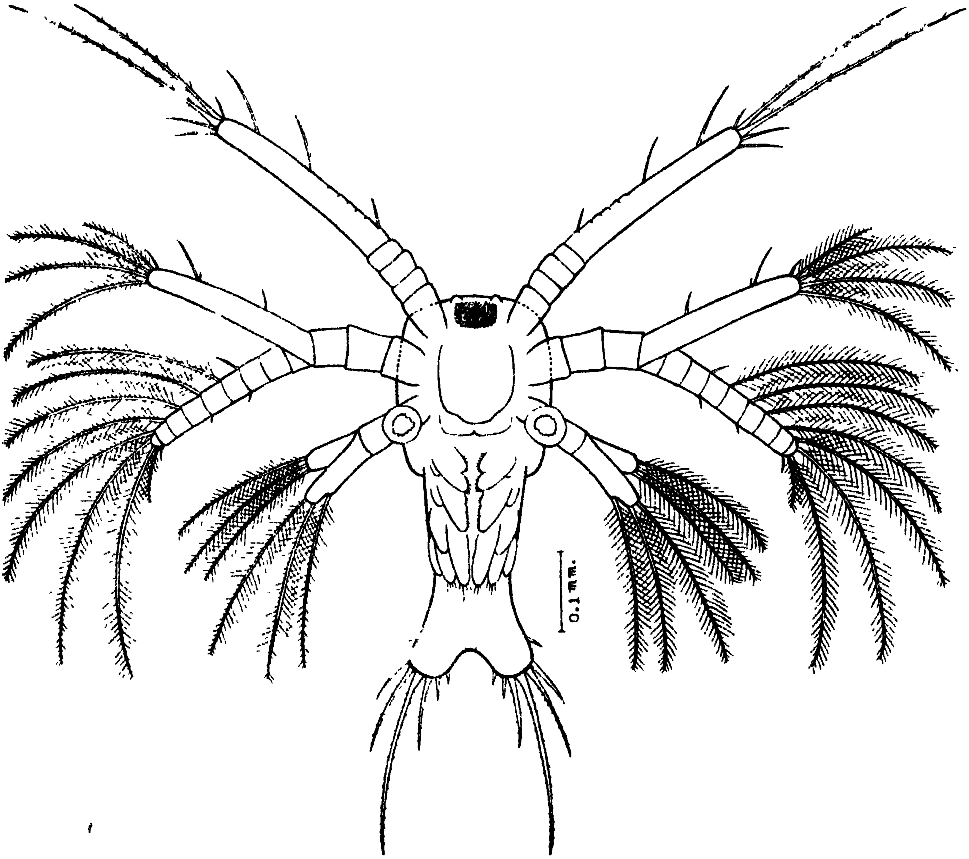

Fig. 11. 6th nauplius, ventral view.

Sixth Nauplius (Fig. 11; Pl. XXIX, Fig. VI): — On completing the 5th moult the nauplius passes into the 6th nauplius about 23 hours after hatching in water of temperature of from 27° to 29 C. In 10 specimens the body-length was from 0.48 to 0.51 mm and the body-width from 0.18 to 0.20 mm.

The characteristic of this substage is that the rudimental carapace, which appeared in the preceding substage, becomes distinct on the body-surface.

The length of the carapace is slightly less than $\frac{1}{2}$ the body-length; in dorsal view the carapace being somewhat square in outline.

The 1st appendage grows rather distinctly into 5 articulations. The 5th articulation, being $\frac{2}{3}$ the total length, hence the longest of all, becomes articulated still further. A short seta appears anew at the tip resulting in the outside seta getting closer to the tip. This, however, is sometimes missing.

An additional small seta that grows at the tip of the endopodite of the second appendage increases the setae to 5, and the addition of 1 tiny seta on the side increases the number on the side to 3. Adding 2 small setae on the outside, the exopodite has 12 setae with 9 articulations. These 2 small new setae on the outside, however, are sometimes lacking.

The swelling on the 3rd appendage takes the shape of a Japanese mortar, the inside ring looking like saw-teeth. Before the nauplius passes into a zoea, owing to the muscle of the endopodite gradually shrinking toward the protopodite, the endopodite becomes practically empty.

The 4 pairs of appendages from the 1st maxilla to the 2nd maxillipede protrude still further. Although they are not yet articulated and rudimental and not functioning, their outlines resemble more that of the zoea.

Furcal development at the posterior end being more pronounced, each spine grows afresh inside resulting in spine formula 7+7.

iii. *Zoea*

The nauplius after completing the 6th moult passes into the 1st zoea about 36 to 37 hours after hatching in water of temperature ranging from 27° to 29°C. After the 6th moult the body elongates considerably and changes are noticed in its appearance and swimming behavior.

In the nauplius stage swimming is accomplished by means of the 3 anterior appendages, but when it has advanced into the zoea stage, the endopodite and exopodite of the 3rd appendages drop off, they being only intended for mastication. The 4 pairs of appendages that appear anew in the nauplius stage markedly develop, the 1st and 2nd maxillipedes joining in the swimming action. But much of the swimming is done by the 1st and 2nd appendages as in the preceding stage. Because of elongation of the lower half of the body, bodily motion becomes slower than in the preceding stage and it swims leisurely by moving its appendages in a paddle fashion.

Its reaction toward light is as strong as before, and although it tends to move in the direction of the light-source, it avoids direct sun-light.

The zoea moults 3 times, after which it becomes a mysis. From the writer's observation of the zoea, besides *P. japonicus*, in *P. monoceros* and *P. affinis*, the number of moults was found to be 3 in both species. Heldt (1939) and Pearson (1939) also reported that they observed 3 moults in the species that they studied. Gurney (1927) also reported as a result of comparative studies of numerous larvae of *P. stebbingi* that the zoea of this species passes 3 substages. It may be said, therefore, that in every species of Peneidae studied up to the present the zoea may be divided into 3 substages.

The time required from hatching to the 1st zoea under the same water temperature is practically invariable. The time from the 1st zoea to its metamorphosis into a mysis varies considerably with the method of rearing even under the same temperature of water. The quickest moults 3 times within 5 days at a water temperature of from 27° to 29°C and passes into a mysis, while the others reared under unfavorable condition took as much as 18 days before they became mysis. The method of rearing will be described later.

The body-colour in the zoea stage is usually pale yellow and translucent, except that the tips of the 1st and 2nd appendages and the posterior end of the body are more brownish-yellow than the other parts of the body.

It may be said that in Crustacea the body-length increases only by moulting, but in some species there is a slight difference in the length immediately after one moult and before the next, an outstanding example of which is the zoea stage of *P. japonicus.* For example, the body-length of the 1st zoea immediately after it has transformed from the nauplius is from 0.87 to 0.93 mm, the average of 10 specimens being 0.92 mm. But the body-length immediately before it reaches the 2nd zoea is from 1.20 to 1.32 mm, while the average of 10 specimens is 1.30 mm, in other words, the 1st zoea increases during the substage its body-length by almost 40% before the next moult.

First Zoea (Fig. 12, I; Pl. XXX; Pl. XXXI): The body-width of a specimen whose body-length is 0.87 mm, is 0.33 mm, as measured at the widest part of the carapace.

The carapace, which is an irregular octagon in shape and a little longer than ½ the body-length, covers the body loosely from the anterior end to the 8th somite, its side flexing somewhat inside (Fig. 12, I). A pair of frontal organs from the nauplius stage, which is still present slightly below the anterior end, drops off from the second zoea.

At the beginning of this substage the compound eyes are not yet visible (Pl. XXXI, Fig. A) but at the end they project considerably (Pl. XXXI, Fig B).

The lower half of the body, which is not covered by the carapace and which is quite slender consists of 6 somites, all of which are classified as thorax somites. The part that adjoins the thorax somite is slightly swollen with 2 somites faintly visible beneath the cuticle (Pl. XXXI, Fig. A). This swelling disappears at the end of this substage, being replaced by 5 somites which are abdominal somites. The boundary between the abdominal somite and the telson is not yet clear (Pl. XXXI, Fig. B).

The well-developed telson with its semi-spherical notch looks like a forked tail. According to Pearson (1939) the shape of the notch is regarded as a characteristic in classifying the species. The number of spines at the top is 7+7, being equal to that of the 6th nauplius, the longest exceeding ⅓ the body-length (Pl. XXX).

The 1st appendage (Pl. XXX) has 3 articulations, the 1st of them having 5 still smaller articulations. The 2nd articulation, which is the longest, bears 3 setae internally and 1 seta externally. The last articulation bears 1 setae at its tip and 2 on its side; of the 4 at the tip, one is particularly long exceeding the body-length.

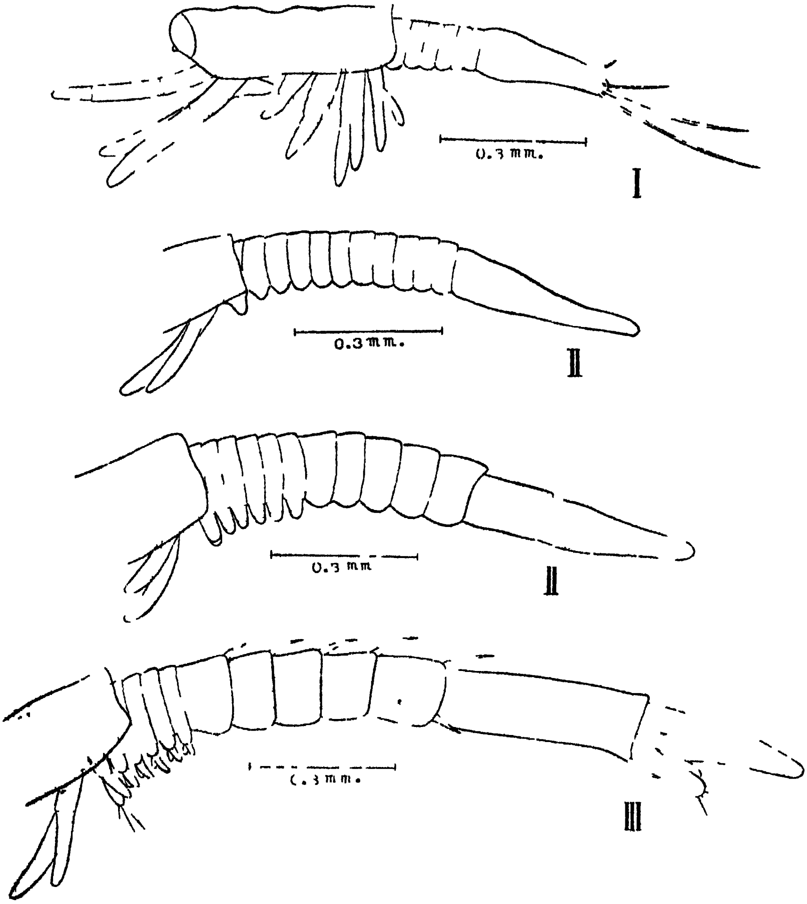

Fig. 12 1st 3rd zoea, lateral view Roman numerals show number of substages

The 2nd appendage (Pl. XXX) is either as long as or slightly longer than the 1st appendage. The protopodite has 3 articulations, the endopodite 2 and the exopodite 10. The 1st articulation of the endopodite, which is longer than twice the length of the 2nd articulation, has 4 setae internally, 2 of them at the joint between the 1st and 2nd articulations and 1 between the 1st articulation and the protopodite. The 2nd articulation bears 4 long and 1 short setae at its tip. The exopodite has 12 setae, the same as that of the 6th nauplius, 10 of them occurring internally to the tip one following the other, and the remaining 2 outside.

The mandible (Pl. XXXI, Fig. C) having lost both endopodite and exopodite at this substage and with nothing remaining but a mark of the exopodite masticates the food The masticatory surface is serrated with its upper part having larger but fewer teeth and the lower part smaller but more number of teeth. Bate (1888) called the former psalistoma and the latter the molar process.

Although the protopodite of the 1st maxilla (Pl. XXXI, Fig. D) has no articulation, it branches into 2 lobes on its inner side with the 1st lobe bearing 7 or 8 setae and the 2nd lobe 5 setae. The endopodite is composed of 3 articulations, the 1st having 3 setae, the 2nd 2 and the 3rd 5. The exopodite or scaphognathite, which is quite small and spherical, has 4 long plumose setae around it.

The 2nd maxilla (Pl. XXXI, Fig. E) is like the 1st, but somewhat larger. The protopodite which is not articulated has 5 small lobes on the inner margin, the 1st having from 7 to 9 setae and the remainder from 2 to 4. The endopodite consists of 4 segments, the terminal one having at its tip 3 long setae and the rest 2 inside of each segment. The exopodite or scaphognathite is spherical with 5 long plumose setae around it.

The labrum, which is oval and pointed at the end, covers the mandible. The labrium is located below the mandible and bifurcated at the end with small thick setae.

The protopodite of the 1st maxillipede (Pl. XXXI, Fig. F) consists of 2 segments, the 1st on the inner margin having from 4 to 6 setae and the 2nd from 12 to 15. The endopodite, which is composed of 4 segments, have 5 setae at the terminal, while each of the remaining segments has 2 or 3 setae. The exopodite, which is slightly shorter than the endopodite, has 3 setae at its tip and 4 on the outerside. No articulation is seen between it and the protopodite.

Although the 2nd maxillipede (Pl. XXXI, Fig. G) resembles the 1st, it is somewhat smaller; and the protopodite, which is faintly articulated by 2 joints, has 4 or 5 setae on its inner margin. The endopodite is composed of 1 segments, the distal segment having 5 setae at its tip and the remaining segments 1 seta each. The exopodite, which is slightly shorter than the endopodite, has 3 setae at its end and a like number outside.

Second Zoea (Fig. 13): — By rearing suitably the 1st zoea passes into the 2nd within 30 or 40 hours in water of temperature of from 27° to 29°C. In the beginning of this substage the body-length is from 1.33 to 1.65 mm which, at the end of the same substage, in 10 specimens, increased to from 1.85 to 2.13 mm. In a specimen whose body-length measured 1.37 mm the body-width was 0.40 mm.

The characteristic of this substage is that a pair of compound eyes appears with the rostrum at the front part of the carapace. The anlage of the compound eye is seen in the preceding substage. The eye fully develops beneath the carapace before the larva passes into a 2nd zoea and protrudes outside immediately after it becomes a 2nd zoea (Fig. 13).

When the body-length was 1.37 mm, the carapace measures 0.57 mm and the width 0.40 mm. The carapace extending from the front part to the 3rd thoracic somite covers them as in the preceding substage. The rostrum, which appears in front of the carapace, measures slightly less than ½ the carapace, its end being slightly decurved. The carapace also has a pair of spines the supra-orbital spines whose length are slightly more than or as much as ½ the rostrum; on the outer side there is in addition a smaller spine near the tip of this one.

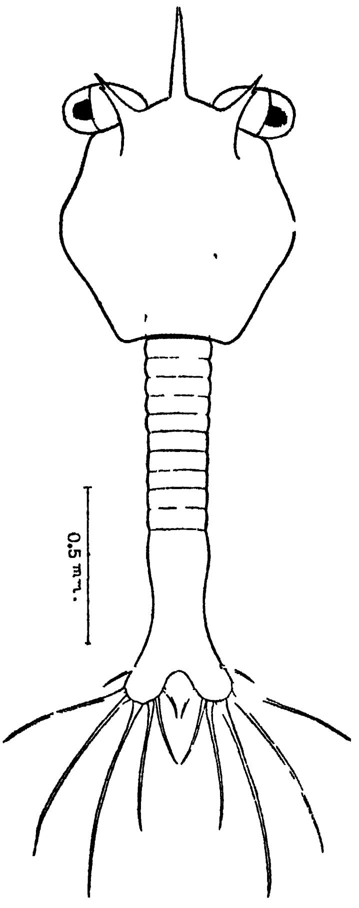

Fig. 13 2nd zoea, dorsal view

At the beginning of this substage a rudiment of the 3rd maxillipede appears at the 3rd thoracic somite (Fig. 12, II), and in the closing period of this substage the rudiments of the appendages of 5 thoracic somites appear (Fig. 12, II'). The rudiments of these appendages are all biramous. Excluding the rudiment of the 3rd maxillipede the endopodites are slightly shorter than the exopodites. These 5 appendages are the rudiments of the pereiopods.

Compared with the preceding substage the 5 abdominal somites are more distinct, but the line between the 6th somite and the telson is not discernible. A rudiment of the uropod faintly appears under the cuticle (Fig. 12, II') toward the end of this substage. The number of spines on the forked tail remains 7 + 7, as in the preceding substage.

No change is seen in the appendages between the 1st antenna and the 2nd maxillipede.

Third Zoea (Fig. 14): By rearing suitably the 2nd zoea passes into the 3rd zoea after 30 or 40 hours in water of temperature from 27° to 29° C. The body-length of 10 measured specimens in the beginning of the period ranged from 2.14 to 2.30 mm and at the conclusion of the same period from 2.33 to 2.59 mm. When the body-length was 2.15 mm, the body-width measured 0.45 mm.

The characteristic of this substage is that the uropods appear near the posterior end and that all the somites fully develop (Fig. 14, A).

The carapace measured 0.70 mm and its width was 0.15 mm when the body-length was 2.15 mm. Its shape covering posteriorly up to the 5th thoracic somite remains practically the same as in the 2nd zoea. The small spines at the tips of the pair of supra-orbital spines at the anterior margin of the carapace disappear.

The 6 pairs of appendages of the thoracic somites, which began to appear faintly at the preceding substage, have slightly developed, the endopodite of the 3rd maxillipede being slightly longer than the exopodite and having three short setae at its tip (Fig. 12. III).

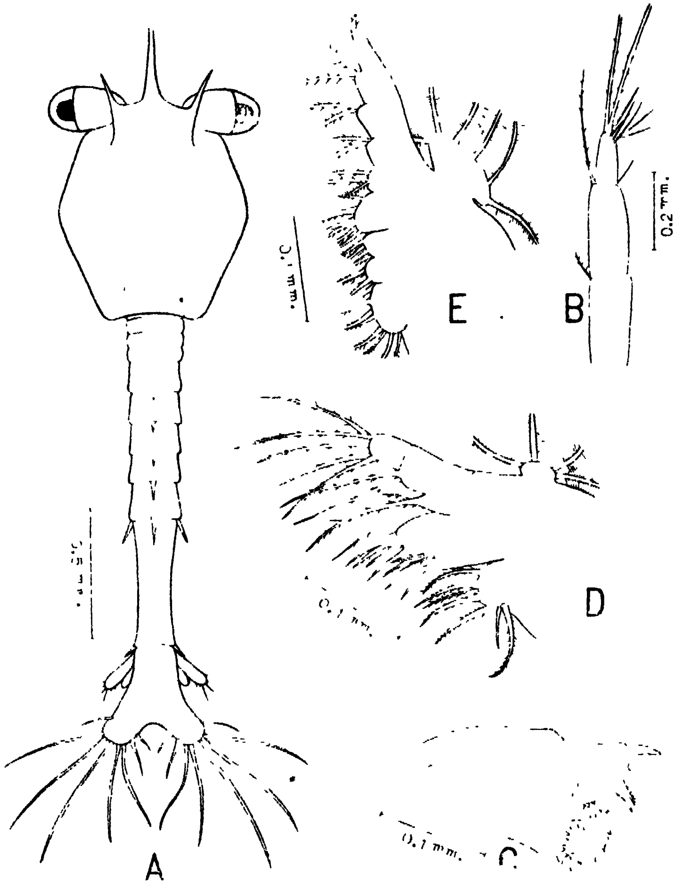

Fig. 14. 3rd zoea and its main parts. A. Dorsal view; B. 1st antenna, C. Mandible; D. 1st maxilla; E. 2nd maxilla

With considerable growth of the 6 abdominal somites the first 5 somites are almost the same in length, each of them being provided with a spine on the dorsal median line at the lower edge. The 5th somite has, besides, a pair of postero-lateral spines, and the 6th abdominal somite being the longest measures $\frac{3}{4}$ of the preceding 5 somites combined and has a pair of lateral and postero-lateral spines (Fig. 12. III; Fig. 11. A).

The uropods which appear externally now, are rudimentary in their structure. The exopodite, which is slightly longer than the endopodite, has 6 or 7 short setae at the tip and near it. Adding a pair of small spines their number at the posterior end totals 8 + 8.

As the result of the union of 5 small articulations the 1st segment of the

1st appendage becomes one whole segment. The 2nd segment does not change while the 3rd one increases 2 or 3 small setae at its tip (Fig. 14, B).

The molar process of the mandible widens and numerous small teeth appear inside (Fig. 14, C).

The 2 lobes of the protopodite of the 1st maxilla markedly protrude (Fig. 14, D).

By the addition of 2 long plumose setae the number of setae on the exopodite of the 2nd maxilla increases to 6 (Fig. 14, E).

No changes are seen on the 2nd antenna, the 1st and 2nd maxillipedes.

iv. *Mysis*

The zoea passes into the 1st mysis after the 3rd moult. If sufficiently fed, larvae in the mysis stage in water at temperature of from 27° to 29°C moult 3 times within 5 days and pass into post-larvae after the 3rd moult. Besides *P. japonicus*, the writer observed also 3 moults in the mysis of *P. monoceros* and *P. affinis*. Pearson (1939) and Heldt (1939) reported, however, the existence of certain species that moult more than 3 times, or became post-larva after only 2 moults (see Table 5).

Table 5

Number of moults in the mysis stage.

Species	Number of moults	Observer
P. japonicus	3	Hudinaga
P. monoceros	3	,,
P. affinis	3	,,
P. trisulcatus	4	Heldt
S. carinata	1	,,
Parapenaeus longirostris	14	,,
Gennadas elegans	4	,,
Solenocera membranacea	2	,,
P. setiferus	2	Pearson
T. constrictus	2	,,

The body of a mysis greatly resembles the adult prawn. The cephalic and thoracic parts unite and the carapace covers the cephalothorax.

Although the function of the 1st and 2nd appendages were mainly natatory up to the preceding stage, they are no more so in this stage; the antennae become tactile in function. Swimming is now accomplished by the 5 pairs of pereiopods that develop in this stage assisted by 3 maxillipedes, their structures being shown in Fig. 15. Although the strong larvae in the preceding stage used to swim in the middle or upper layers of the water, in the mysis stage even the strong ones swim in the lowest layer. Most of them, however, swim in the middle and upper layers of the water. They usually suspend themselves in the water with their head down and the telson up rapidly moving their 5 pairs of pereiopods. When moving about, their heads stay downward and proceed with the telson ahead and the body somewhat aslant. The tendency to move in the direction of the light-source is noticed less frequently.

The body color is a pale-yellow, while the color of the mouth parts, thorax, abdominal segments and the tip of the 1st antenna is reddish-brown, whereas in the 3rd mysis it is pale yellowish-brown.

In the mysis stage the larva a every moult gradually changes its body-form. The writer will, therefore, not divide the stage into substages in describing the mysis, but will proceed with the changes that occur in the various parts.

Body-Length and Width: - The body-lengths of 10 examined specimens in the 1st mysis ranged from 2.67 to 3.10 mm, in the 2nd from 2.99 to 3.64 mm and in the 3rd from 3.79 to 4.52 mm. The body-width measured 0.53 mm in the 1st mysis when the body-length was 2.87 mm; 0.56 mm in the 2nd when the body-length was 3.61 mm and 0.59 mm in the 3rd when the body-length was 4.27 mm.

Carapace and Rostrum (Pl. XXXII, Figs. I, II and III):—The carapace which is more developed than in the zoea stage is almost as matured as in an adult prawn. In this stage the thoracic and cephalic segments completely unite and the carapace covers them, its length measuring about $\frac{1}{3}$ the body-length. A pair of supra-orbital spines which lie at the front margin and at both sides of the base of the rostrum becomes smaller than in the preceding stage, becoming still smaller after each moult. A pair of antero-lateral spines appears slightly below the middle of the anterior margin of the carapace, besides a pair of hepatic spines that also appear, one on each side of the carapace behind the eye and slightly set back from the anterior margin of the carapace.

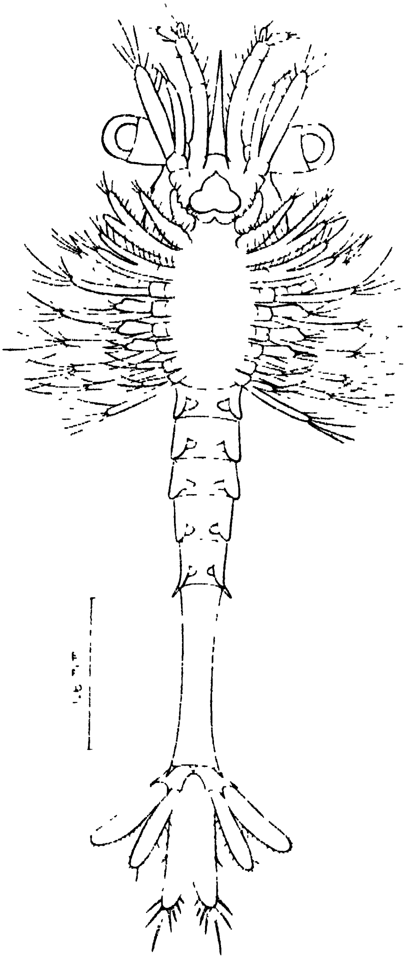

Fig. 15. 1st mysis, ventral view.

The length of the rostrum slightly exceeds ½ that of the carapace, the front part being decurved in the 1st and 2nd mysis, whereas in the 3rd mysis length is slightly less than ½ the carapace and straight; its tip is slightly longer than the eye-stalk in the 1st and 2nd mysis but almost equal to the eye-stalk in the 3rd.

In the 1st mysis no teeth are found on the dorsal side of the rostrum, although 1 appears in the 2nd mysis and 2 in the 3rd. Frequently only one tooth is found in the 3rd mysis.

Abdomen (Pl. XXXII, Figs. I′, II′ and III′): – The well-developed abdomen is slightly less than ½ the body-length in the 1st mysis and slightly more than ½ in the 2nd and 3rd. The anterior 5 segments are almost of the same length. The 6th segment, which is the longest, is slightly shorter than the whole length of the 5 segments combined. In the 1st mysis the spines on the 1st and 2nd segments disappear. The spine on the 3rd segment disappears in the 2nd mysis and that on the 4th segment becomes quite small in the 3rd mysis, while that on the 5th segment is the only one whose presence is definite. Although no spines were found on the median line of the 6th segment at the postero-dorsal margin in the preceding stage, a long spine appears in the mysis stage. Although the number of lateral spines is the same as in the preceding substage, they have become smaller in size. At this stage a spine appears between the telson and the abdomen on the median line at the postero-ventral margin.

Telson and Uropod (Fig 16): – The telson is slightly less than 1/5 the body-

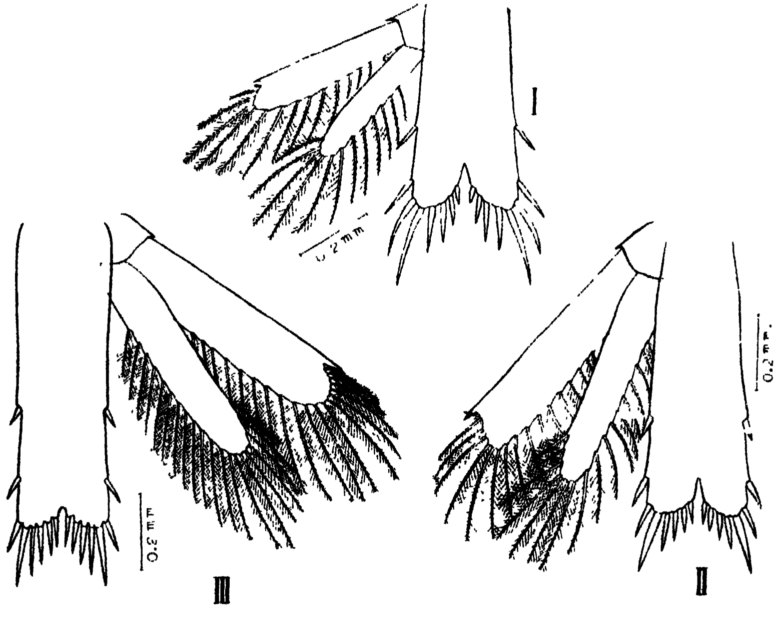

Fig. 16. Telson and uropod in mysis stage, dorsal view. Roman numerals show number of substages.

length. With the drawing closer toward each other of the bifurcated ends of the distal margin the notch becomes smaller. This notch becomes still smaller at each moult in this stage. That is, whereas the height of the tip of the notch is between the lateral 1st and 2nd spines at the 1st mysis, the tip is on the same line as the 2nd spine in the 2nd mysis; in the 3rd, the tip is at that height between the 2nd and 3rd spines. The spine formula being the same as that of the preceding substage is 8+8.

The uropod is well developed in this stage, and a spine appears at the edge of the outside of the protopodite. The exopodite is slightly longer than the endopodite, but shorter than the telson throughout the 1st, 2nd and 3rd mysis. The exopodite, which bears a small spine on the outer distal margin, also bears from 14 to 15 plumose setae at the distal and lateral-inner margin in the 1st mysis, from 17 to 20 in the 2nd and from 22 to 25 in the 3rd. The endopodite bears at the distal and lateral-inner margin from 12 to 13 plumose setae in the 1st mysis, from 17 to 20 in the 2nd and from 20 to 23 in the 3rd.

First Antenna (Fig. 17): - In the 1st mysis the stem has 3 segments, of which the 1st is the longest. The anlage of the otolith appears outside of the base of the 1st segment, which bears 2 or 3 small setae. 1 spine occurs at the inner side and slightly above the middle. The length of the 2nd segment, which is ½ that of the 1st, has several setae on both sides of it. The 3rd segment, which is slightly shorter than the 2nd, bears several setae on both sides and 2 branches at the distal end. The outer branch, which is about twice as long as the inner, has 6 sensory setae at the end, the inner having 2 at the end. These sensory setae are special being found only on the outer branch of the 1st antenna.

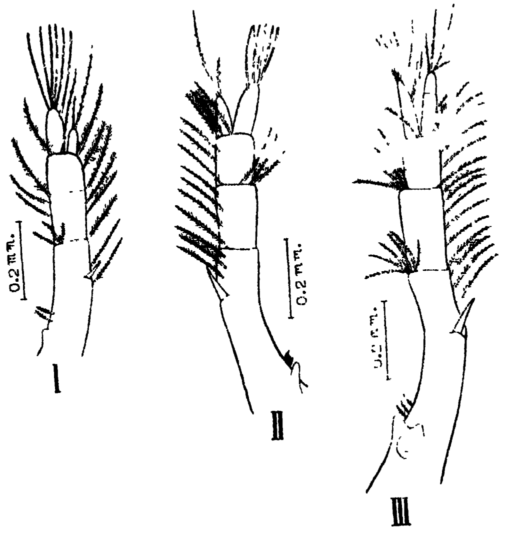

Fig. 17. 1st antenna in mysis stage. Roman numerals show number of substages

The antenna remains essentially the same at the 2nd mysis as in the 1st. The length of the 1st segment is more than twice that of the 2nd; in the case of those at the end of the 3rd segment the inner branch is about ⅔ that of the outer.

The length of the 1st segment exceeds twice that of the 2nd segment at the 3rd mysis and the otolith at the base becomes clearly visible. As to the branches at the end of the 3rd segment they have the same length or the outer branch is slightly shorter than the inner. The last named, which is indistinctly segmented into 2, has 4 sensory setae at the terminal and 3 on the side. On the other hand, the inner branch which is segmented into 3 bears 4 setae at the terminal. The number of setae around each segment of the stem increases more or less.

Second Antenna (Fig. 18) : — In the 1st mysis, the protopodite being composed of 2 segments, there appears inside the 1st segment a tiny swelling which is the anlage of the green gland. The segments disappear from both endopodite and exopodite, and the flattened exopodite bears 10 long plumose setae at the tip and on the inside, while the endopodite, which is shorter than the exopodite and of a rod-like shape, bears 4 setae at the tip and 3 simple setae inside.

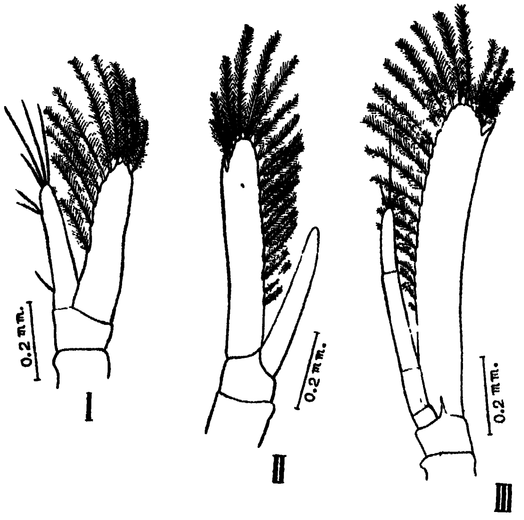

Fig. 18. 2nd antenna in mysis stage. Roman numerals show number of substages.

A small spine appears on the 2nd segment of the protopodite in the 2nd mysis. The exopodite terminates with a sharp spine at the outer tip. With the number of setae increasing from 18 to 20 their lengths become fairly shorter than those at the preceding substage. The length of the endopodite is $\frac{2}{3}$ that of the exopodite; the setae are lacking.

The exopodite is further flattened in the 3rd mysis bearing from 23 to 25 setae. The endopodite, somewhat longer than $\frac{1}{2}$ the exopodite, is divided into 4 segments, of which the 1st is very short, the 3rd the longest and the 4th, which is the terminal segment, bearing 3 or 4 simple setae at the end.

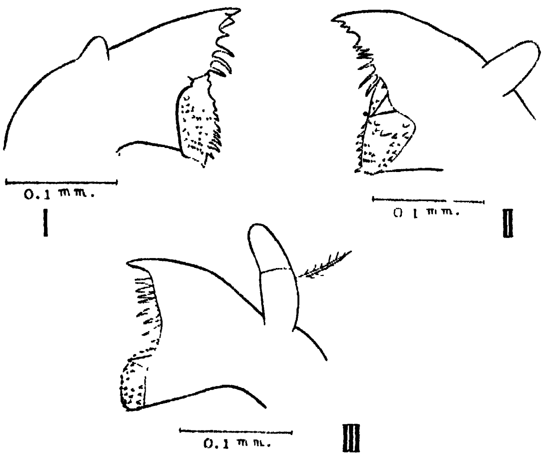

Fig. 19. Mandible in mysis stage. Roman numerals show number of substages.

Mandible (Fig. 19) : — The masticatory surface of the mandible remains the same throughout the mysis stage. The psalistoma is sharper than at the preceding stage, the molar process is flattened still further and the number of small teeth increases. A small protrusion, which appears at the upper margin of the peduncle in the 1st mysis, grows still longer in the 2nd and divides into two segment in the 3rd bearing one seta on its side.

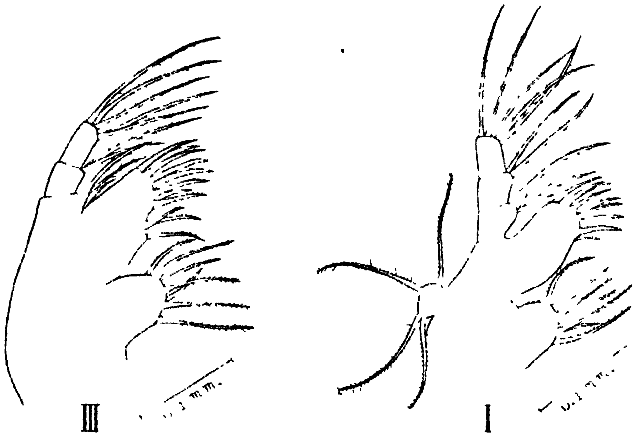

Fig. 20. 1st maxilla in mysis stage. Roman numerals show number of substages.

First Maxilla (Fig. 20): — In the 1st mysis, this appendage remains almost the same as that in the zoea, excepting that the 2nd lobe of the protopodite protrudes more than in the preceding stage. It is also exactly the same in the 2nd mysis as in the 1st.

The exopodite drops off in the 3rd mysis, the size of the endopodite diminishing considerably compared with that of the protopodite. The articulation between the 1st segment and the protopodite becomes indistinct.

Second Maxilla (Fig. 21): — The structure of the 2nd maxilla

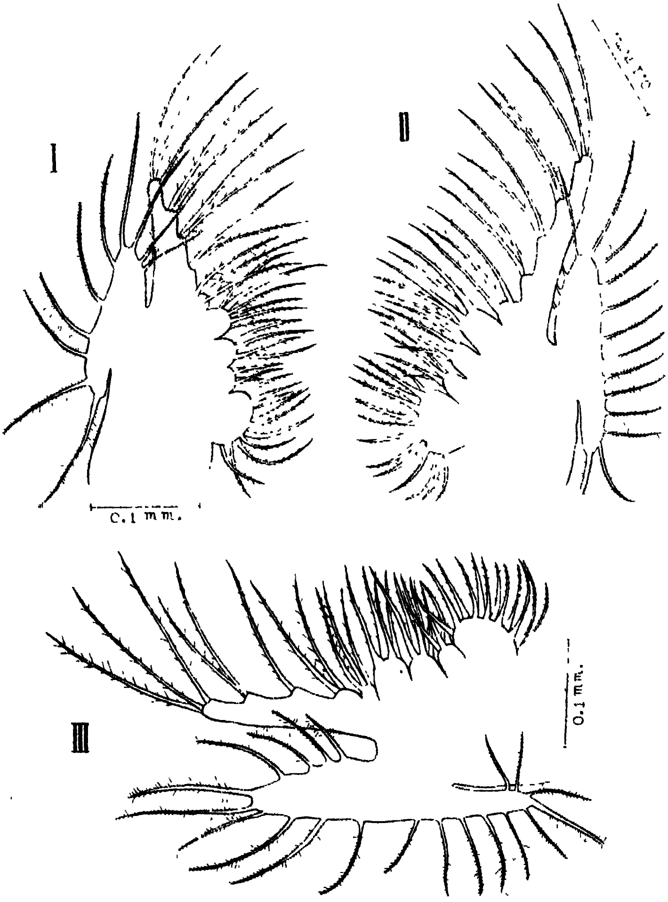

Fig. 21. 2nd maxilla in mysis stage. Roman numerals show number of substages.

remains the same as that in the zoea, excepting that the exopodite or scaphognathite is developed much more than in the preceding stage, whereas in the 3rd mysis the scaphognathite of the 1st maxilla falls away. This scaphognathite gradually increases in size with each moult, the long pulmodial setae around it also increasing to 10 in the 1st mysis, 16 in the 2nd and 20 in the 3rd. *First Maxillipede* (Fig. 22): —The structure of this appendage does not change throughout the mysis stage remaining the same as in the zoea, excepting that the exopodite has anew a number of setae postero-laterally. In the 2nd mysis, the mastigobranchial plate, which appears near the base of the protopodite and which is too small to be visible, develops in the 3rd mysis to a rather large size and becomes distinct (mb).

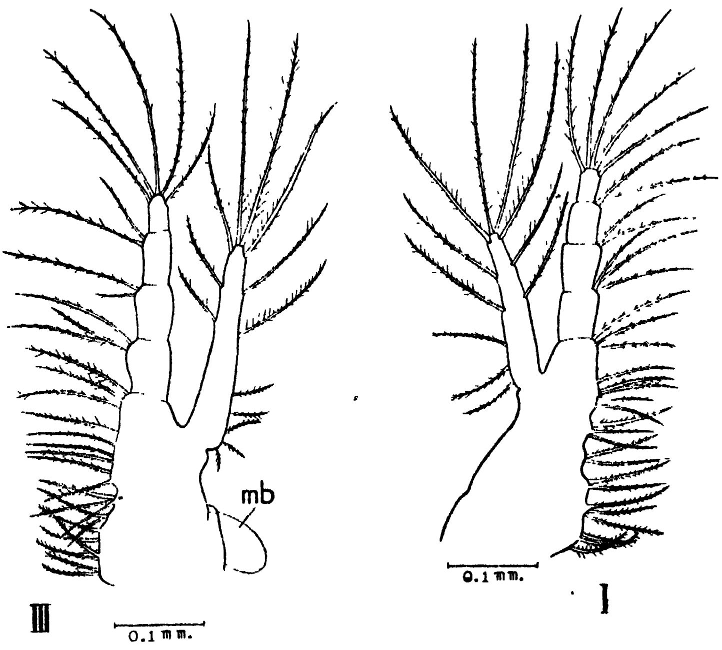

Fig. 22. 1st maxillipede in mysis stage. Roman numerals show number of substages.

Second Maxillipede (Fig. 23): —In the 1st and 2nd mysis, its structure remains essentially the same as in the zoea. In the 3rd mysis the endopodite is provided with 5 segments, of which the 2nd is the longest, the 4th next in length, the 5th slightly shorter than the 4th, and the 1st and 3rd shorter still than ½ that of the 2nd. As to the setae, the 3rd segment has none, while the 1st, 2nd and 4th segment each have 2 or 3 long setae on the inner side, while the 5th has 3 at the tip and 2 near the tip in addition to seta at the line between it and the 4th segment. No change is seen in the exopodite.

As in the case of the 1st maxillipede, the mastigobranchial plate faintly appears at the base of the protopodite in the 2nd mysis, becoming distinct in the 3rd (mb).

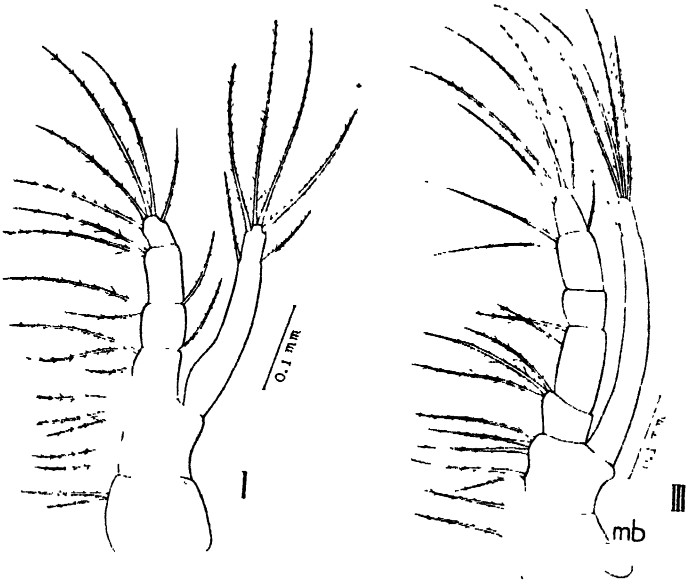

Fig. 23. 2nd maxillipede in mysis stage. Roman numerals show number of substages. *mb*, mastigobranchia.

Third Maxillipede (Fig. 24): — This appendage, together with the 5 pairs of pereiopods to be described below develops considerably in the mysis stage. The protopodite has 2 segments, the endopodite 5 and the exopodite none. Of the 5 segments of the endopodite in the 1st mysis, the 2nd and 4th are the longest, the 3rd and 4th equal to $\frac{2}{3}$ of the 2nd, and the 1st the shortest being only $\frac{1}{2}$ that of the 2nd. The 2nd segment of the protopodite and the 1st to the 4th of the endopodite each have 2 or 3 setae on their sides, while the 5th has 5 at its tip. The 3rd maxillipede in the 2nd and 3rd mysis remains the same as that in the 1st mysis, and the lengths of the segments of the

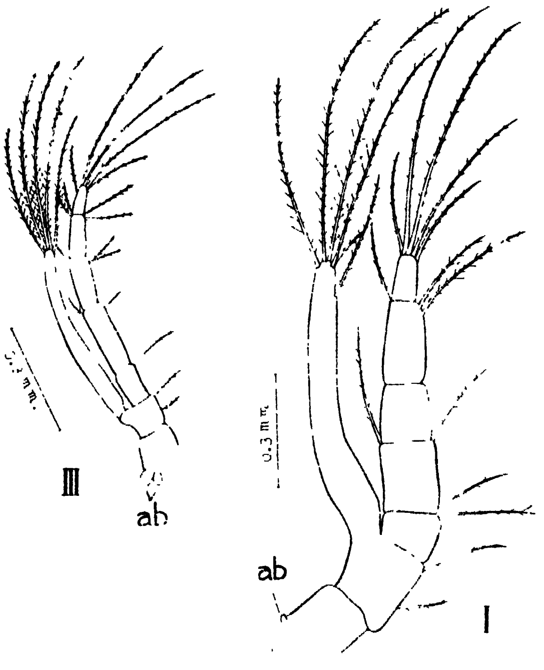

Fig. 24. 3rd maxillipede in mysis stage. Roman numerals show number of substages. *ab*, arthrobranchia.

endopodite slightly differ from those in the 1st mysis.

An arthrobranchia (ab) that faintly appears at the base of the protopodite in the 1st mysis is scarcely visible. Another arthrobranchia appears in the 2nd mysis. Although the one becomes somewhat clearer in the 2nd mysis, the new one is still indistinct. These 2 arthrobranchiae are visible for the first time in the 3rd mysis, although frequently only one arthrobranchia can be found.

First to Fifth Pereiopods (Pl. XXXIII): -- The protopodite consists of 2 segments in the 1st mysis, none being found on either endopodite or exopodite; the exopodites are either twice as long as or longer than the endopodites in all the 5 pairs of pereiopods. The anlages of the chelae appear at the tips of the first 3 pairs of the endopodites. The endopodite of each appendage has 4 or 5 long simple setae at its tip, while the exopodite has 4 at the tip and 3 or 4 long pulmodial setae on the side.

In the 2nd mysis, the endopodite of each appendage becomes longer than $\frac{1}{2}$ the exopodite, the first 3 pairs being segmented into 4 and the remaining 2 pairs into 5. The tips of the first 3 pairs become chelae, but neither propodite nor carpopodite are distinguishable yet. As to the first 3 pairs, the lengths of the 1st to the 3rd segment are nearly the same, the length of the 4th being twice that of the others. The segments of the remaining 2 pairs of endopodite, from the 1st to the 3rd segment, have the same length, while the 4th and 5th segments are slightly shorter than twice the other segments. The exopodite remains the same as at the preceding substage.

In the 3rd mysis, the first 3 pairs of the endopodite are also segmented into 5, the propodite and the carpopodite being clearly differentiated and developed in order to complete the chelae. The endopodite of the 1st pereiopod is slightly shorter than the exopodite, while that of the 2nd pereiopod is almost equal in length to the exopodite. The endopodite of the 3rd pereiopod is thus longer by about $1\frac{1}{2}$ times the exopodite. The endopodites of the remaining 2 pairs of pereiopods are slightly longer than the exopodites. The structure of the exopodites of each pereiopod remains the same as in the preceding substages.

In the 1st mysis, an arthrobranchia (ab) faintly appears at the base of the protopodites of from the 1st to the 3rd pereiopods, while in the 2nd mysis another one faintly appears in these pereiopods. Even in the 2nd mysis, these arthrobranchiae are too small to be visible until, when the 3rd mysis is reached, they become rather distinguishable; an arthrobranchia appears very faintly on the 4th pereiopod.

First to Fifth Pleopods (Pl. XXXII, Fig. I′, II′ and III′): —The 5 pairs of appendages that belong to the abdomen are yet rudimentary and functionless in the mysis stage. These appendages, which appear as buds ventrally in the 1st mysis, become slightly more pronounced in the 2nd. Every appendage that is developed in the 3rd mysis, is articulated into 2 segments with 2 or 3 very short setae at the tips.

v. *Post-larva*

The 3rd mysis passes into the 1st post-larva. Its 5 pairs of pleopods, which were functionless in the preceding stage, serve for swimming, while the pereiopods, which fulfilled the main function of swimming in the mysis stage, now serve for grasping food and crawling (Fig. 25). With growth of the larvae and with change of the stage swimming function is gradually taken over by the appendages that have newly appeared (See Table 6).

Table 6

Change in swimming appendages

Stage	Appendages for swimming	
	Principal	Subordinate
Nauplius	1st 2nd antennae	Mandible
Zoea	1st-2nd antennae	1st 2nd maxillipedes
Mysis	1st-5th pereiopods	1st-3rd maxillipedes
Post-larva	1st 5th pleopods	Uropod

At the beginning of this stage the larvae which lived until then as plankton and swam horizontally through the water begin to creep on the sand after undergoing 3 or 4 moults. Unlike the adult, however, they creep on or sink into the sand during the day as well as at night with irregular intervals. The habit of creeping on the sand like the adults appears after they have completed from 10 to 12 moults.

With every moult the form and various structures of its body undergo gradual transformation and come to resemble the adult. After undergoing approximately from 20 to 22 moults the form of the body and its appendages become the same as those of the adult.

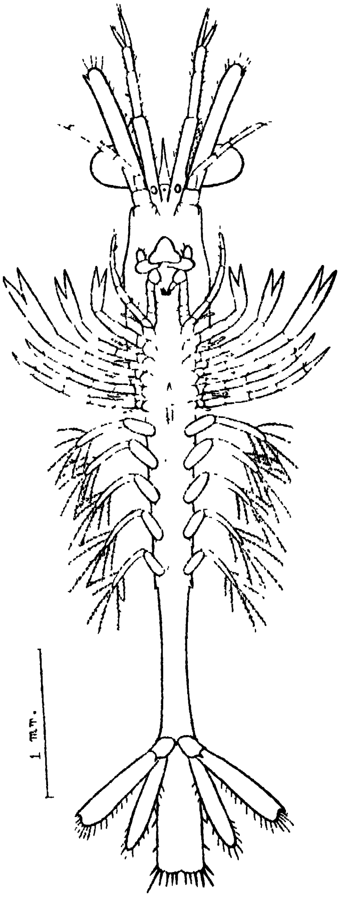

Fig. 25. 1st post-larva, ventral view.

At the beginning of this stage the colour of the body is pale brownish-yellow, the same as that in the 3rd mysis, but after 4 or 5 moults, complicated colours, such as brownish-black, greenish-black, brownish-yellow etc., appear in various parts of the body. These colour spots increase with the number of moults, eventually changing to the colour peculiar to this prawn approximately 40 days after incubation, when its body-length exceeds 6 cm.

Table 7

Body-length and growth percentage at every moult, 10 specimens measured at every substage

Substage	Body length			Growth percentage
	Maximum	Minimum	Average	
	mm	mm	mm	%
1st nauplius	0.34	0.30	0.32	0.0
2nd „	0.35	0.33	0.34	6.2
3rd „	0.38	0.35	0.37	8.8
4th „	0.42	0.38	0.39	5.5
5th „	0.45	0.42	0.44	12.8
6th „	0.51	0.48	0.50	13.6
1st zoea early	0.93	0.87	0.92	86.0
„ later	1.32	1.26	1.30	39.7
2nd „ early	1.65	1.33	1.53	25.4
„ later	2.13	1.85	1.97	28.7
3rd „ early	2.32	2.14	2.24	13.7
„ later	2.59	2.33	2.50	11.1
1st mysis	3.10	2.67	2.83	13.2
2nd „	3.64	2.99	3.34	22.2
3rd „	4.52	3.79	4.34	21.0
1st post-larva	5.00	4.79	4.90	12.6
2nd „	5.74	5.20	5.71	16.5
3rd „	6.39	5.80	6.24	9.2
4th „	6.92	6.37	6.76	8.3
5th „	7.50	6.67	7.31	8.1
6th „	7.87	6.85	7.69	5.1
7th „	8.31	7.20	8.15	6.0
8th „	10.38	8.35	9.01	10.5
9th „	11.10	8.56	9.88	9.7
10th „	12.31	9.40	10.88	10.0
11th „	13.45	10.41	11.57	6.3
12th „	14.51	11.39	12.40	7.1
13th „	17.10	12.41	14.15	14.1
14th „	19.12	13.72	15.80	11.6
15th „	23.00	15.12	19.50	23.4
16th „	26.54	17.95	21.00	7.7
17th „	30.12	19.15	24.32	15.8
18th „	33.10	21.92	30.11	23.8
19th „	36.23	24.85	35.25	17.1
20th „	38.12	28.51	37.52	6.4
21st „	40.25	31.67	40.10	6.9
22nd „	42.58	33.82	42.31	5.5

Body-Length and Body-Width: — As to the body-length and body-width in the post-larval stage, the writer will summarize the development percentages of the body-length and the comparisons made of the body-length and body-width

Table 8

Length of body and its main parts

Substage	Body-length	Body-width	Length of carapace	Length of abdomen			Length of telson
				Total	1st to 5th seg.	6th seg.	
1st nauplius	mm 0.32	mm 0.17					
2nd ,,	0.34	0.17					
3rd ,,	0.36	0.18					
4th ,,	0.40	0.18					
5th ,,	0.43	0.18					
6th ,,	0.49	0.19					
1st zoea	0.90	0.34	mm 0.50				
2nd ,,	1.75	0.44	0.64				
3rd ,,	2.14	0.57	0.80	mm 0.97	mm 0.53	mm 0.44	mm 0.37
1st mysis	2.87	0.53	0.90	1.40	0.76	0.64	0.57
2nd ,,	3.61	0.56	1.04	1.90	1.04	0.86	0.70
3rd ,,	4.27	0.59	1.12	2.32	1.28	1.01	0.83
1st post-larva	4.79	0.60	1.36	2.55	1.37	1.18	0.88
2nd ,,	5.74	0.63	1.60	3.07	1.65	1.42	1.07
3rd ,,	6.02	0.65	1.68	3.36	1.79	1.47	1.07
4th ,,	6.43	0.67	1.76	3.60	2.08	1.52	1.07
5th ,,	6.49	0.77	1.80	3.61	2.09	1.52	1.08
6th ,,	7.29	0.99	2.24	3.97	2.40	1.57	1.08
7th ,,	7.70	1.12	2.42	4.07	2.42	1.65	1.21
8th ,,	10.38	1.76	3.01	5.72	3.74	1.95	1.65
9th ,,	10.90	1.76	3.10	6.16	3.96	2.20	1.65
10th ,,	11.59	1.87	3.52	6.38	4.18	2.20	1.69
11th ,,	13.35	2.20	3.86	7.59	5.17	2.42	1.91
12th ,,	14.48	2.50	4.60	7.76	5.20	2.56	2.12
13th ,,	17.08	3.00	5.12	9.56	6.60	2.96	2.40
14th ,,	19.02	3.19	5.50	11.36	7.82	3.50	3.20
15th ,,	23.00	3.64	7.50	12.30	8.60	3.70	3.20
16th ,,	26.00	3.90	8.50	14.00	10.00	4.00	3.50
17th ,,	29.40	4.01	9.52	15.90	11.30	4.63	4.01
18th ,,	31.60	4.20	10.30	17.15	12.25	4.90	4.15
19th ,,	32.60	4.35	10.71	17.17	12.82	4.92	4.20
20th ,,	34.62	4.50	11.10	19.02	13.62	5.40	4.50
21st ,,	35.55	4.80	11.14	19.61	14.20	5.41	4.80
22nd ,,	36.55	5.00	11.20	19.95	14.50	5.45	5.40

on each ecdysis of the 1st nauplius up to the 22nd post-larva (See Tables 7, 8, 9 A, and Figs. 26 and 27 A).

The development percentage of the nauplius during its early stage at each ecdysis, which is below 10 per cent, exceeds it towards the final stage. When the 6th nauplius undergoes ecdysis and becomes the 1st zoea the development percentage rises to 86 per cent, and its body-length becomes almost twice as large in proportion. This development percentage, being the maximum throughout the course of ecdyses, does not attain to a body-length twice as much with a single process of ecdysis in the latter.

What characterizes this body-development during the zoea stage, as already explained, is the large difference in body length at the beginning and the end of the same substage without undergoing ecdysis. During the zoea stage, however, this difference is most marked in the 1st zoea, decreasing in the 2nd and 3rd zoea. In the 1st zoea the development percentage during the same substage is nearly 10 per cent. This high development percentage rank second to that when the 6th nauplius passes into the 1st zoea. There is no other high development percentage during ecdyses. The 2nd zoea attains a development percentage of 28 per cent during the same substage, the 3rd zoea 11 per cent showing a gradual decrease in the percentage. A similar tendency may be noticed in the development percentage when going through ecdysis during the zoea stage. Although a development percentage of 25 and above is attained at the time of passage from the 1st to the 2nd zoea, it is only 13.7 per cent at the time it passes from the 2nd to the 3rd zoea a decrease of nearly $\frac{1}{2}$. When the 3rd zoea passes into the 1st mysis, its development percentage is 13.2. The high development percentage, such as that when the 6th nauplius passes into the 1st zoea, cannot be seen any more.

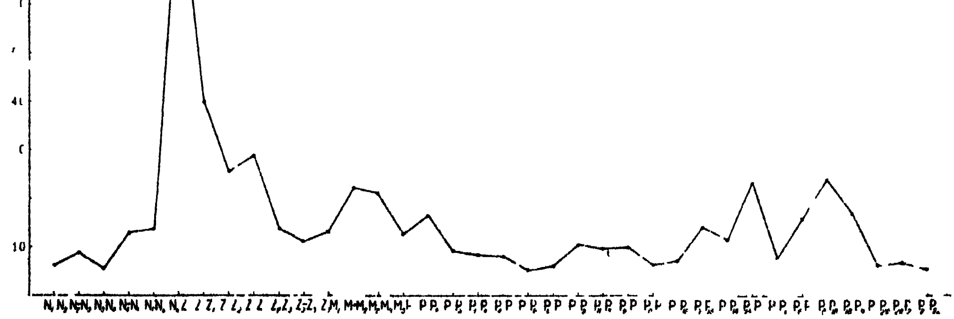

Fig. 26. Growth percentage by moulting from 1st nauplius to 22nd post-larva.

Table 9

Ratio of body parts

A: $\frac{\text{body-width}}{\text{body-length}} \times 100$, B: $\frac{\text{carapace}}{\text{body-length}} \times 100$,

C: $\frac{\text{rostrum}}{\text{carapace}} \times 100$, D: $\frac{\text{abdomen}}{\text{body-length}} \times 100$,

E: $\frac{\text{6th abdominal segment}}{\text{1st–5th abdominal segs.}} \times 100$, F: $\frac{\text{telson}}{\text{body-length}} \times 100$.

Substage	A	B	C	D	E	F
1st nauplius	53.1					
2nd ,,	50.0					
3rd ,,	50.0					
4th ,,	45.0					
5th ,,	41.7					
6th ,,	39.5					
1st zoea	37.0	55.5				
2nd ,,	25.2	36.5	37.5			
3rd ,,	24.5	37.3	43.7	58.0	83.0	17.2
1st mysis	18.1	31.3	51.1	48.7	84.2	19.8
2nd ,,	15.5	28.8	45.2	53.1	81.2	19.3
3rd ,,	13.8	26.2	43.7	54.3	81.2	19.4
1st post-larva	10.4	28.3	31.1	53.6	86.1	18.4
2nd ,,	10.6	27.9	24.5	53.4	86.0	18.6
3rd ,,	10.7	27.9	23.8	55.8	82.1	18.6
4th ,,	10.4	27.3	21.5	55.9	73.0	16.6
5th ,,	11.8	27.7	23.1	55.6	72.7	16.6
6th ,,	13.4	30.7	24.5	54.4	65.4	14.8
7th ,,	14.5	30.1	27.2	52.8	68.1	15.7
8th ,,	16.9	28.9	27.7	55.2	52.9	15.8
9th ,,	16.1	28.4		56.5	55.5	15.1
10th ,,	16.1	30.3	30.3	55.0	52.6	14.5
11th ,,	16.4	28.8	34.8	56.8	46.8	14.3
12th ,,	17.2	31.7	34.7	53.5	49.2	14.6
13th ,,	17.5	29.9	32.8	55.9	44.8	14.0
14th ,,	16.6	28.9		59.5	44.7	16.8
15th ,,	15.8	32.5	36.2	64.6	43.0	13.9
16th ,,	15.0	32.6	48.1	53.8	40.0	13.4
17th ,,	13.6	32.3	47.5	54.0	40.7	13.6
18th ,,	13.2	32.5	47.7	54.2	40.0	13.1
19th ,,	13.3	32.8	47.6	54.2	38.2	12.8
20th ,,	12.9	32.0	47.9	54.4	39.6	12.9
21st ,,	13.5	30.4	47.8	55.1	38.0	13.5
22nd ,,	13.6	30.6	46.4	54.5	37.5	14.7

In two preceding substages the development percentage during the mysis stage exceeds 20, which is larger than that when the larva passes from the 3rd zoea into the 1st mysis, and also higher than 12.6 per cent when it passes from the 3rd mysis into the 1st post-larva.

The development percentage during the post-larval stage is very irregular. In the course of ecdyses from the 1st to the 22nd post-larva, there are only two occasions when the development rises above 20 per cent, 7 occasions when it is 10 per cent or slightly more, while on all other occasions they drop below 10 per cent. It is during the zoea and mysis stages that the highest development percentage of the larvae is reached.

The largest ratio between the body-length and body-width is seen in the nauplius stage. During the beginning of this stage, the ratio of body-width to body-length is 50 per cent, or one-half, and with the 1st nauplius, more than one-half. This ratio drops as development proceeds, so later gradually outgrows the body-width. The body form becomes slender with each ecdysis. The minimum ratio is seen during the period from the 1st to the 4th post-larva, when the body-width becomes $^1/_{10}$ the body-length. It is during this stage that the body becomes most slender. A tendency for this ratio of gradual increase in body-width may be seen after the 5th post-larva, after which it again declines with the 13th post-larva, until from the 17th or 18th post-larva it is practically constant (See Table 9 A; Fig. 27, A).

Carapace and Rostrum (Pls. XXXIV and XXXV): -- The length of the rostrum in the 1st post-larva as in the 3rd mysis is almost as long as the eye stalk. With every ecdysis, however, it becomes shorter than the eye stalk reaching minimum in the 4th post-larva, when it is then almost $\frac{1}{2}$ the eye stalk. From the 5th post-larva it again gradually increases in length, while in the 8th post-larva the rostrum is either only slightly shorter than the eye stalk or is of the same length. In the 9th post-larva the rostrum, which becomes longer than the eye stalk, is about $1\frac{1}{2}$ times longer than the eye stalk in the 16th or 18th post-larva, the ratio of the two becoming definite.

The number of teeth on the centro-median line of the rostrum and the carapace are 3 in the 1st post-larva, 4 in the 2nd, 5 in the 4th, 6 in the 5th, 7 in the 6th, 8 in the 9th, 9 in the 11th and 10 in the 13th, beyond which it does not increase. There are, however, exceptions to the foregoing rule, the increase not always being in the manner described. It may cease increasing after attaining 9 teeth (sometimes we see 11 teeth), but in the majority of cases the increase ceases after the 10 teeth has been reached. A tooth that grows on the underside of the rostrum and formed during the 10th or 11th post-larva does not multiply (See Table 10).

Although the supra-orbital spine that is located on the anterior edge of the carapace at the base of the rostrum during the mysis stage disappears in the 1st post-larva, but it re-appears in the 10th or 11th post-larva. The antero-lateral spine and the hepatic spine formed from the mysis stage gradually grows longer, stronger and sharper during ecdyses. A keel is formed under the hepatic spine in the 8th or 9th post-larva. The 2 keels are formed in the 17th or 18th post-larva on the line that joins the supra-orbital spine and the hepatic spine, as also on the line that joins the antero lateral spine and the hepatic spine. The keels become clear with development of the larva. The 3 grooves on the centro-median line of the carapace and constituting one of the characteristics of *P japonicus* may faintly be perceived from the 17th post-larva and quite clearly in the 20th post-larva.

Table 10

Number of teeth on rostrum in the mysis and post larval stages

M, mysis; P, post-larva

Substage / Rostrum	M_1	M	M	P_1	P	P_3	P_4	P	P	P	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}	P_{14}
Upper	0	1	2	3	4	4	5	6	7	7	7	8	8	9	9	10	10
Lower	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1

As shown in Table 9, C and Fig. 27, C, the ratio of rostrum to carapace, which is 31.1 per cent in the 1st post larva, gradually decreases until it reaches a minimum of 21.5 per cent in the 4th post-larva, where it again gradually

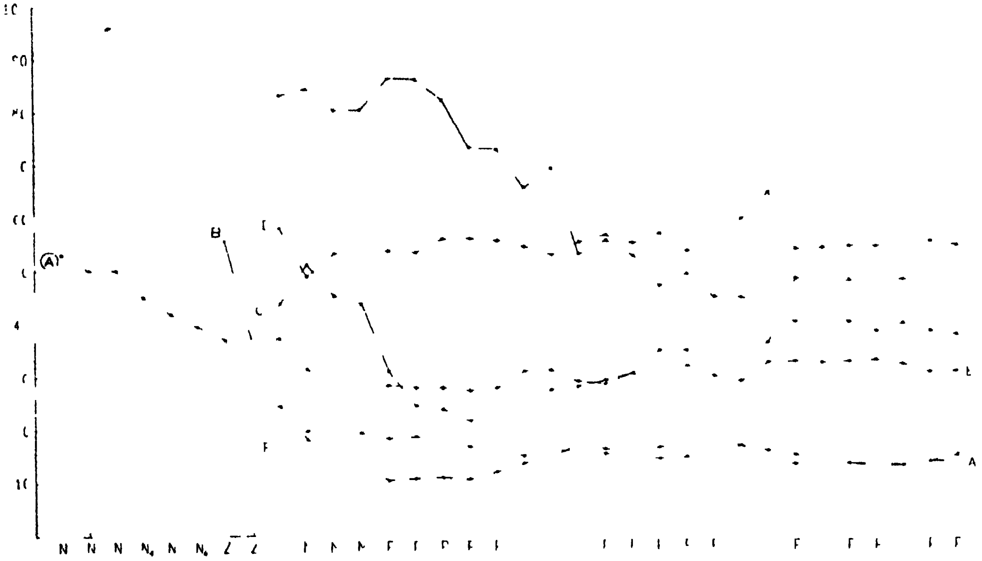

Fig 27 Ratio of body length to main parts of body at every substage

A $\frac{\text{body width}}{\text{body-length}} \times 100$, B $\frac{\text{carapace}}{\text{body length}} \times 100$,

C $\frac{\text{rostrum}}{\text{carapace}} \times 100$, D $\frac{\text{abdomen}}{\text{body length}} \times 100$

E $\frac{\text{6th abdominal seg}}{\text{1st 5th abdominal segs}} \times 100$ F $\frac{\text{telson}}{\text{body length}} \times 100$

increases, reaching 48.1 per cent in the 16th post-larva, after which it is constant — a ratio very similar to that between the rostrum and the eye stalk.

The ratio between the carapace and body-length (Table 9, B; Fig. 27, B) ranges from 27 to 28 per cent during the period from the 1st to the 5th post-larva, gradually increasing from the 6th post-larva, becoming 32.5 per cent around the 15th post-larva, after which it becomes invariable.

Abdomen: -- The abdomen in the 1st post-larva scarcely differs from that in the 3rd mysis. There is a spine each on the postero-median line from the 4th to the 6th somites, that on the 6th somite being the longest and that on the 4th somite very short. The spines on the 4th and 5th somites disappear when it passes into the 2nd and 3rd post-larvae. The spine on the 6th somite also shortens greatly. The spines located on the latero-median line of the 5th and 6th somites from the mysis stage are very short in the 1st post-larva. The spine on the 6th somite disappears on passing into the 2nd post-larva, while that on the 5th somite disappears in the 5th post-larva.

As in the mysis stage, the 6th somite is much longer than the other somites in the beginning of the post-larval stage. With successive ecdysis, however, it gradually shortens. As will be seen from Table 9, E and Fig. 27, E, the length of the 6th somite is 86.1 per cent of the length from the 1st to the 5th somites in the 1st post-larva, gradually decreasing, however, to 40 per cent in the 16th post-larva, whence it becomes almost invariable.

The ratio of body-length to the length of the entire abdomen is, as shown in Table 9, D and Fig. 27, D, from 50 to 60 per cent, beyond which it does not change much.

Telson and Uropod (Fig. 28; Pl. XXXVI): Although a small notch still persists on the middle part of the tip of telson during the 1st and 2nd post-larvae, this notch disappears completely in the 3rd post-larva, becoming straight as if it had been amputated. The tip gradually projects outward from the 4th post-larva. A tiny projection that shows itself on the middle part of the tip in the 5th post-larva gradually extends with successive ecdysis. When the tip of the telson gradually assumes a convex shape and the projection in the middle gradually becomes larger, the number of spines on the tip gradually diminishes. The 3 lateral pairs of spines do not, however, disappear, but still remain when the adult stage is reached. These 3 pairs of spines on the telson are one of the characteristics of *P. japonicus.* The spine formula for the respective sub-stages of the post-larva as given in Table 11 is 8 + 8 from the 1st to the 7th post-larva, same as at the mysis stage. From the 8th post-larva, however, there is the decrease of a pair with every ecdysis until it becomes 4 + 4 in the 11th post-larva, which stops decreasing on becoming 3 + 3 in the 14th post-larva. The disappearance of these spines, however, is not regular. It may lose 2 pairs at one time, or it may lose only half a pair leaving behind the other half.

The groove on the median line on the surface of the telson may be faintly seen from the 8th post-larva and rather clearly in the 10th post-larva. 4 feathered setae on the tip and 10 each on the lateral sides appear in the 5th post-larva. The number of these setae increases with every ecdysis.

As shown in Table 9. F and Fig. 27. F, the ratio between the telson and the body-length shows scarcely any change in that at the beginning of the post-larva and that at the end.

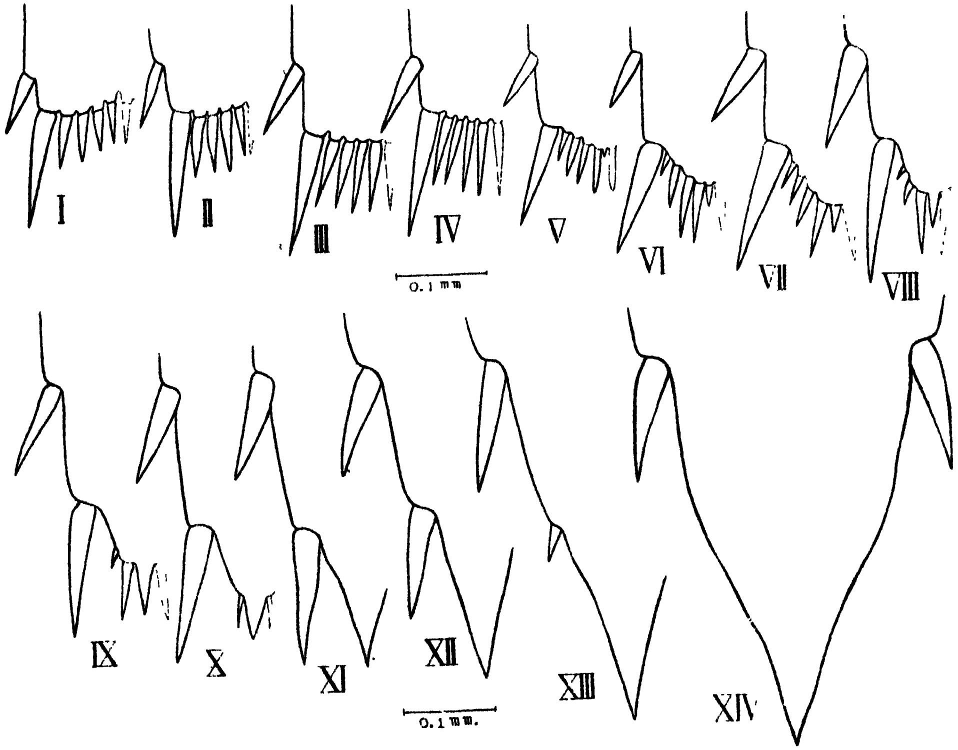

Fig. 28. Telson in post-larval stage. Roman numerals show number of substages.

Table 11

Spine formula of post-larval stage

Substage	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV
Spine formula	8+8	8+8	8+8	8+8	8+8	8+8	8+8	7+7	6+6	5+5	4+4	4+4	4+4	3+3

The uropod is almost the same as that in the 3rd mysis as in the 1st post-larva, the exopodite is slightly longer than the endopodite, but a little shorter than the telson. In the 5th post-larva, the uropod is longer than the telson, whence forward the ratio between the two gradually widens. In the 14th post-larva the uropod becomes 1½ times as long as the telson, no marked changes being seen afterwards. The setae around the exopodite and endopodite increase in number with repeated ecdysis.

First Antenna (Pl. XXXVII): — The change in the 1st antenna may be seen in the 1st joint and the 2 branches on the tip of the 3rd joint; hardly any change is seen in the 2nd and 3rd joints.

The 1st joint, which is longer than that of the others, is twice or more longer than the 2nd one. There are scarcely any marked differences in the beginning of the post-larva compared with the 3rd mysis. The 1st joint slightly turns back- and upward in the middle, the otolith being visible at its base. A sharp spine is found in the center of the inside. In the 4th post-larva, that part where the eye joints, becomes rather hollowed, where the setae grow thickly around it. The otolith is found where the base of the hollow is deep, which hollow, however, shallows toward the tip. The structure of the base of the hollow becomes complicated with every ecdysis. In the 8th post-larva, the prosartema (Bate 1888), which grows in innerside gradually lengthens. Upon reaching the 22nd post-larva, the length of the prosartema becomes almost $\frac{1}{2}$ that of the 1st joint with long, soft cilia growing around its periphery. At the 8th post-larva, a sharp tooth grows on the opposite side of the prosartema, which tooth also gradually develops but is not so long as the prosartema. In the 22nd post-larva, the length of the sharp tooth is slightly less than $\frac{1}{2}$ the prosartema with long cilia growing around its circumference. The sharp spine on the inside that was present during the beginning of the post-larval stage persists until the 8th post-larva, whence it disappears, being replaced by a sharp spine on the exterior tip at the boundary of the second joint. Very few setae are found on the lateral side of the 1st joint during the beginning of the post-larva, but they increase as in the case of the 2nd and 3rd joints with every ecdysis.

The 2 branches on the tip of the 3rd joint scarcely differ in the 1st post-larva from that in the 3rd mysis. The inner branch consists of 3 joints and the outer branch of 2. The number of segments of the 2 branches increases with every ecdysis (See Table 12). The ratio of length of the outer branch

Table 12

Number of segments in the branches of 1st antenna in post-larval stage

Substage Branch	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI	XXII
Inner	3	4	4	5	5	5	6	6	8	9	9	12	13	15	16	17	17	17	17	18	19	20
Outer	2	3	3	3	5	5	7	7	8	10	10	11	12	14	15	16	16	16	16	16	19	21

to that of the inner is large during the period from the 1st to the 3rd post-larva, the outer branch being almost $\frac{2}{3}$ as large as the inner. The difference in ratio between the two branches decreases later, the lengths of the two becoming almost the same in the 13th post-larva. The length and position of the sensory hair which, at the beginning of the post-larva, does not differ from that in the mysis stage, is located on the tip of the outer branch and near the tip of the side. In the 4th post-larva, however, there is no sensory hair on the joint at the tip, but only on the 2nd joint. In the 5th post-larva, there is none on the 2nd joint at the tip, but on the 3 rear joints. With the increase in the number of segments later, there is none at the 4th and the 5th joints at the tip, but only on the lower segments. With increase in the number of segments, those both at and near the tip taper, compared with those on the base a feature that is especially notable on the outer branch.

Second Antenna (Pl. XXXVIII) : —There is scarcely any difference at the beginning of the post-larval stage compared with that in the 3rd mysis. The swelling of the green gland appears on the inner side of the 1st joint of the peduncle. The size of this knot gradually diminishes until it can scarcely be seen in the 9th post-larva.

Until the 4th post-larva the exopodite or scaphocerite is the same as that in the 3rd mysis. It is of sheath-shape, the lower half being smaller than the upper. The width of the upper and lower halves is same in the 5th post-larva. The lower half then gradually becomes wider than the upper half, while its exterior edge becomes thick and strong. The number of setae on the tip and on the inside increases with every ecdysis and their lengths gradually shorten.

The endopodite, which is shorter than the exopodite in the 1st post-larva and which becomes of almost the same length in the 2nd post-larva. rapidly grows longer with every ecdysis, eventually becoming approximately $\frac{1}{2}$ the body-length in the 7th post-larva, while in the 14th post-larva, it becomes longer than the body-length. and in the 22nd post-larva almost $1\frac{1}{2}$ times that of the body-length (Table 13). The number of segments also rapidly increases with growth.

Table 13

Ratio of body-length to flagellum of 2nd antenna at post-larval stage

$$\frac{\text{flagellum}}{\text{body-length}} \times 100$$

Substage	I	II	III	IV	V	VI	VII	VIII	IX	XI	XII	XIII	XIV	XXII
%	23.0	24.5	25.2	25.8	31.5	39.6	49.8	51.4	52.8	72.7	93.5	94.1	101.5	139.2

Mandible (Pl. XXXIX) : --In the 1st post-larva, the number of teeth in the grasping part of the mandible or the psalistoma decreases, but they become very sharp compared with what they were in the preceding stage. The number of surface teeth in its grinding part or the molar process also decreases. The edge between the former and the latter becomes as keen as that of a razor. The teeth of the psalistoma and the molar process decrease in number with every ecdysis, while in the 4th post-larva the molar process loses its teeth and becomes flat and smooth leaving only 2 or 3 strong sharp teeth of the psalistoma which at the 20th post-larva also loses its teeth, the pointed tip of the masticatory surface becoming smooth and strong.

The synaphipod which developed during the mysis stage becomes longer in the 1st post-larva, having 5 setae on its tip and 3 or 4 on its periphery. The synaphipod has 2 joints or only one in the 1st post-larva, whereas in the 2nd post-larva it invariably has 2 joints, the 1st with 3 or 4 setae on the side and several short setae near the boundary of the 2nd joint, the last-named being round with 8 or 10 setae on its periphery. Full development of the 2nd joint follows later with every ecdysis, eventually becoming flat. The setae on the periphery become plumose and gradually increase in number. Upon reaching the 6th post-larva later, the circumference is found to have a thick growth of setae. With only the number of setae on its lateral side increasing, there is scarcely any change in the 1st joint.

First Maxilla (Pl. XL): — The 2 lobes of the peduncle in the post-larvae which are well-developed compared with that in the mysis become sharper with increasing setae on the inner side with every ecdysis. Of the 2 lobes, the 2nd is always bigger than the 1st, the difference in size between the 2, although most marked at the beginning of the post-larva, is not so noticeable at the concluding stage. In the 9th post-larva, a growth of setae is seen on the exterior side of the peduncle; this growth does not increase much in the later larvae.

Although the endopodite degenerates in the 1st post-larva and loses all its setae in the 2nd post larva, it begins to develop again from the 5th post-larva with one long seta in the inner side near its tip. A new seta appears inside in the 7th post-larva, with from 6 to 7 short setae appearing on the lower outside. The lower half of the endopodite is proportionately large and its tip slender. This tendency strengthens with ecdysis, the tip slightly projecting in the 9th post-larva, which projection develops suddenly with every ecdysis. In the 9th post-larva, there are 3 setae inside and 7 outside. One of the 3 setae inside is located near the tip, while the other 2 are in a lower position, thus apparently divided into two parts. When it has passed into the 12th post-larva, there are 11 or 12 setae outside, while there are 2 setae on the upper part and 3 on the lower part, besides more in different places. In the 15th post-larva, a long seta appears on the tip, 9 or 10 on the exterior side, and 5 or 6 at the lower part inside. The setae on the tip number 4 in the 17th post-larva, while from 8 to 10 appear on the tip and its vicinity in the 20th post-larva. 5 small teeth appear near the outside in the 15th. post-larva, the number of which neither increases nor decreases with ecdysis. The number of setae on the outside increases with every ecdysis, while those on the lower part inside show little increase. A number of setae appear in the middle inside in the

17th post-larva. With loss of the setae in the 20th post-larva there develops a long spine.

Second Maxilla (Pl. XLI) : --The inner side of the peduncle divides into 4 lobes in the 1st post-larva, the 4th lobe being the largest, followed by the 1st and the 2nd the smallest. The number of setae in each lobe decreases when compared with those in the 3rd mysis. Compared with the 3rd mysis the endopodite greatly degenerates. Although having 3 joints the setae almost disappear, there remaining only 2 or 3 very short ones on the 3rd joint. The scaphognathite, which is well developed, becomes larger compared with that in the 3rd mysis, having from 26 to 28 plumose setae on its periphery.

In general, during the 2nd post-larva each lobe of the peduncle becomes smaller compared with that in the preceding substage. The 1st lobe is especially small having only one seta on its tip. The 2nd lobe, which is comparatively larger than the 1st, has 2 setae on the tip. The 3rd and 4th lobes are the same as in the preceding substage. The endopodite, furthermore, degenerates and becomes smaller than in the preceding substage entirely losing its joints and setae. The scaphognathite furthermore is larger than in the preceding substage having from 33 to 35 plumose setae.

Although the number of its setae increases with every ecdysis, the shape of each lobe of the peduncle does not change much.

In the 5th post-larva, the endopodite has several small teeth on its tip besides a number of small setae lower down, the number of which gradually increases with every ecdysis.

The scaphognathite fully develops with every ecdysis, becomes larger, and the number of plumose setae on its periphery also increases. After the 5th post-larva, it becomes the principal part of this appendage subordinating the other peduncle and endopodite.

First Maxillipede (Pl. XLII) : --In the 1st post-larva, the inside of the peduncle consists of 2 lobes, the 1st lobe sometimes being subdivided into 2 more lobes. The 1st lobe has 7 to 10 setae, while the 2nd lobe has from 17 to 20. The endopodite has markedly degenerated compared with that in the 3rd mysis and does not have any joints, having 3 setae on the tip and 3 on the side. The exopodite also has greatly degenerated, not having any setae. The mastigobranchial. plate (mb) which newly developed in the 2nd mysis exceeds the size.

Scarcely any striking changes are noted in the peduncle in the 2nd post-larva. The endopodite, furthermore, has degenerated and become smaller than the exopodite with only 2 setae. The exopodite becomes slightly larger and flat compared with that in the preceding substage. The mastigobranchial plate, further, becomes larger and flat.

Later, in every ecdysis the setae on the lobes of the peduncle increase and the adjoining part between the peduncle and the lobes narrows.

From the 4th post-larva, the endopodite begins to develop again becoming longer and slender. In the 8th post-larva, it consists of 4 joints and slightly curves. Of the 4 joints the 1st the longest, being as long as the combined lengths of the other 3 joints. The length from the 2nd to the 4th joint is almost the same. Until the 8th post-larva, this branch has only a few setae on its lower part, while 5 or 6 setae develop regularly in a row on the 1st joint upon reaching the 9th post-larva. This group of setae does not increase in number with later ecdysis, only a few setae from those on the 2nd to the 4th joints in the 9th post-larva increasing with every ecdysis. The length of the endopodite, which is shorter than the exopodite until the 11th post-larva, gradually gets longer than the exopodite later.

In the 4th post-larva with every ecdysis, the exopodite gradually develops with setae growing on its tip and neighbourhood, the setae gradually increasing in number around the entire periphery also with every ecdysis.

Setae grow on the mastigobranchial plate for the first time upon passing into the 10th post-larva, its number increasing with later ecdysis.

Second Maxillipede (Pl. XLIII): — In the 1st post-larva the 1st of the 2 joints of the peduncle has 3 setae on the inner side, while the 2nd joint has 7 there. The endopodite with 5 joints is better developed than in the 3rd mysis. The 2nd of the 5 joints is the longest, being twice as large as the others. The 3 joints on the upper part curve inward. The 1st and 2nd joints have from 3 to 5 setae on the inner side, while only the 3rd joint has 1 or 2 setae on the outside. The 4th joint has 1 seta inside and 4 on the out, while the 5th joint has 7 or 8 setae on the tip and its neighbourhood. The exopodite, which has greatly degenerated, is destitute of setae. The mastigobranchia (mb) is, furthermore, better developed than in the 3rd mysis.

In the 2nd post-larva, the 3 joints on the upper part of the endopodite curve further inward, while the exopodite falls off. A podobranchia (pb) on the upper part of the mastigobranchia and an arthrobranchia (ab) on the lower part appear anew.

The 3 joints on the upper part of the endopodite later curve greatly inward with every ecdysis. After the 5th post-larva the 2 joints on the tip folding up on the 3rd joint almost joint the inside of the 2nd joint. Including the 2 joints of the peduncle the number of setae on each joint increases with every ecdysis.

On reaching the 9th post-larva, the exopodite (ex) reappears outside of the 2nd joint of the peduncle lengthening later with every ecdysis and in the 12th post-larva becoming half as long or longer than the endopodite. Several setae appear on its tip and vicinity. Upon reaching the 15th post-larva, its length exceeds that of the endopodite, and more than 20 plumose setae appear on the upper part and the tip. In the 17th post-larva, its length increases to 1½ times that of the endopodite with dense plumose setae around the periphery. Its length is nearly twice that of the endopodite in the 20th post-larva.

The tip of the mastigobranchia (mb) sharpens in the 4th post-larva with 3 long setae appearing on its tip in the 5th post-larva. In the 7th post-larva it becomes slender with increase in the number of setae around its periphery. Its shape gradually becomes palmate with later ecdysis and dense setae appear around the circumference. The podobranchia (pb) and arthrobranchia (ab) which newly appeared in the 2nd post-larva gradually assume a lobulate form developing with every ecdysis. Another arthrobranchia newly appears in the 7th post-larva.

Third Maxillipede (Pl. XLIV): -- Of the 3 pairs of maxillipedes this appendage undergoes the least change. In the 1st post-larva in the 2 joints of the peduncle, the 1st joint does not have any setae, the 2nd joint having 2 setae inside. The endopodite consists of 5 joints, the 2nd being the longest, followed by the 1st and 4th with the 5th the shortest. From 2 to 4 setae appear on the inner side of each joint from the 1st to the 4th, while the 5th or terminal joint has 7 setae on its tip and 3 on the inside. The exopodite, which is greatly degenerated and is destitute of setae in the 1st post-larva, disappears in the 2nd post-larva. The 2 arthrobranchia (ab) are now fairly clear.

The shapes of the peduncle and the endopodite scarcely undergo any change with later ecdysis, except a slight one in the length of each joint on the endopodite. The setae on each joint increase with every ecdysis. 2 to 3 short teeth appear inside of the 1st joint of the endopodite in the 15th post-larva, which number increases with every ecdysis. Upon reaching the 20th post-larva, from 12 to 15 teeth appear in a row inside.

The exopodite (ex) that reappears in the 9th post-larva later increases in length with every ecdysis with setae growing on its periphery. Its length becomes ½ that of the endopodite in the 20th post-larva with dense growth of setae.

The 2 arthrobranchiae (ab) that developed in the mysis stage gradually become lobulate, developing further with every ecdysis. In the 4th post-larva a pleurobranchia (plb) newly develops underneath the arthrobranchiae, becoming clear in the 6th post-larva. The mastigobranchia (mb), which first formed in the 11th post-larva, later becomes palmate as it develops with ecdysis later and a number of long setae grow around the circumference.

First, second and third Pereiopods (Pls. XLV and XLVI): The peduncle consists of 2 joints and the endopodite of 5. The 4th and the 5th joints form a chela. Each joint has short setae, but their number is few if we exclude the chela. The exopodite, which greatly degenerates in the 1st post-larva and is now destitute of setae, disappears in the 2nd post-larva.

The length-ratio of 5 joints of the endopodite gradually changes with every ecdysis. Of these the ratio between the 3rd joint and the 4th is the most marked (See Table 14). Of the 3 pairs of chelae having almost the same structure, that of the 3rd pereiopod is selected for illustration here (Fig. 29). Its tips become ossified in the 1st post-larva with sharp, short setae growing densely around its tip. There are no teeth, however, inside the chela. Upon reaching the 6th post-larva, 5 teeth each grow in a row inside the chela. From 9 to 10 teeth grow in a row in the 11th post-larva, while from 25 to 28 teeth grow in a row in the 20th post-larva. Besides the setae on the tips, groups of from 5 to 8 setae appear in various places on the chela.

The exopodite, which is deciduous in the 2nd post-larva, reappears on the outer side of the protopodite in the 10th post-larva. The 3 setae, which grow on the tip in the 11th post-larva, grow longer with every ecdysis, to say nothing of the increase in the number of setae. Its length, however, is not longer than that of the peduncle.

Table 14

Ratio of 3rd segment to 4th segment of the 1st to 3rd periopods in the post-larval stage

$$\frac{\text{4th seg.}}{\text{3rd seg.}} \times 100.$$

Substage	I			V			X			XV			XX		
Pereiopod	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
%	300.0	240.0	200.0	255.5	142.8	109.3	152.3	100.0	71.4	137.0	77.0	56.2	126.0	64.0	53.3

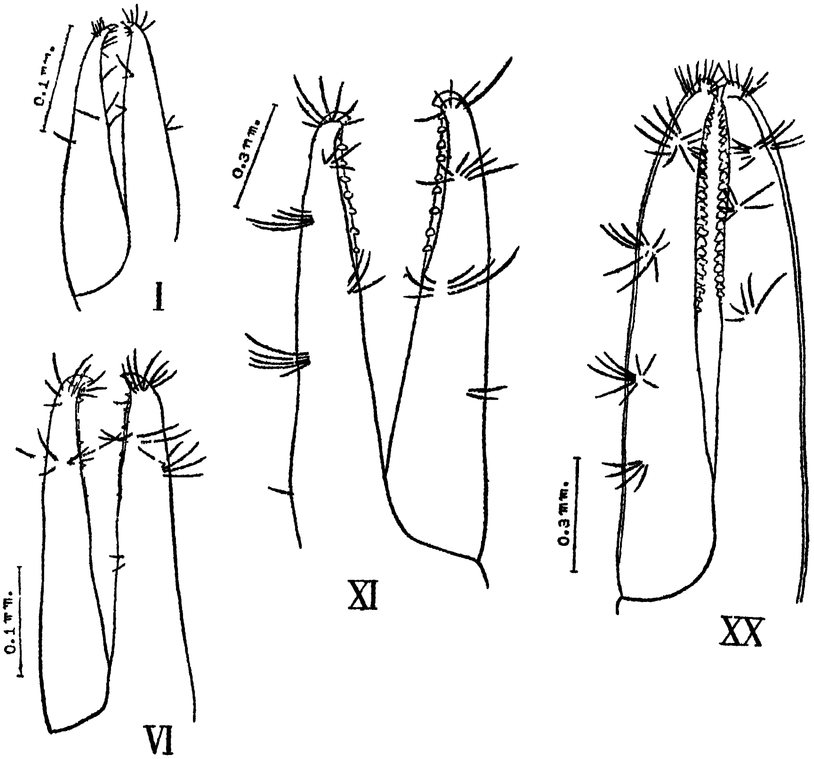

Fig 29 Chela of 3rd pereiopod in post-larval stage Roman numerals show number of substages

The two arthrobranchiae (ab) become lobulate as they develop with every ecdysis.

The pleurobranchia (plb) which develops underneath the arthrobranchiae in the 4th post-larva becomes lobulate with gradual development. The mastigobranchia (mb) first formed in the 6th post-larva becomes palmate with every ecdysis. Dense setae gradually grows around its circumference.

Forth and Fifth Pereiopods (Pls. XLV and XLVI) : — The shape of these pereiopods is almost the same, except that the 5th pereiopod is slightly longer than the 4th. The peduncle consists of 2 joints, the endopodite of 5. The 4th and 5th joints do not constitute the chela. The exopodite, which was present in the 1st post-larva with degenerated structure, sloughs off in the 2nd post-larva.

In the 1st post-larva, the 2nd, 3rd and 4th joints of the endopodite are almost of the same length, the 1st being slightly longer than $\frac{1}{2}$ that of the 2nd, while the 5th is slightly shorter than the 4th. These lengths scarcely change with ecdysis, except that the 4th joint shortens a little compared with the 2nd and 3rd joints.

The exopodite that sloughed away in the 2nd post-larva reappears on the 4th pereiopod in the 10th post-larva, and on the 5th pereiopod in the 11th post-larva. It develops later with every ecdysis, with growth of setae on its periphery. Its length, however, is not longer than that of the peduncle. It is on the 2nd and 3rd maxillipedes that the secondary exopodites become longer, although they do not develop on the 5 pairs of pereiopods.

The one arthrobranchia (ab) that appeared on the 4th pereiopod in the 3rd mysis becomes clear in the 1st post-larva, gradually lobulate, developing with later ecdysis. The 1st to 3rd pereiopods, all have 2 arthrobranchiae each, whereas the 4th pereiopod has only one. This arthrobranchia does not appear in the 5th pereiopod. The pleurobranchia (plb) appears on the 4th pereiopod in the 6th post-larva, while on the 5th pereiopod it first appeared in the 8th post-larva.

The Pleopods (Fig. 30) : — As already described, the pleopods attain full development in the post-larval stage and serve for swimming. The 1st of the 5 pairs of pleopods develop but slowly compared with the remaining 4 pairs. Since all the 4 pairs of pleopods develop almost similarly, the 2nd pair of pleopods is here described.

The peduncle always has no joints. The stem is uniramous during the period from the 1st to the 7th post-larva. The setae of stem number 2 on the tip and from 4 to 5 each on both sides in the 1st post-larva. The length of these setae is slightly less than the stem. The number of setae on both sides later increases with every ecdysis, growing densely on the periphery in the 15th post-larva. In contrast with the increasing number of setae, they gradually shorten in length until they become only $\frac{1}{5}$ of the stem in the 15th post-larva.

On reaching the 8th post-larva, it develops for the first time a tiny inner branch, having no setae yet. It later gradually develops with every ecdysis with gradual growth of setae on its periphery. In the 15th post-larva, the length of the inner branch increases to $\frac{1}{2}$ that of the outer branch, and in the 20th post-larva to $\frac{2}{3}$ the outer branch.

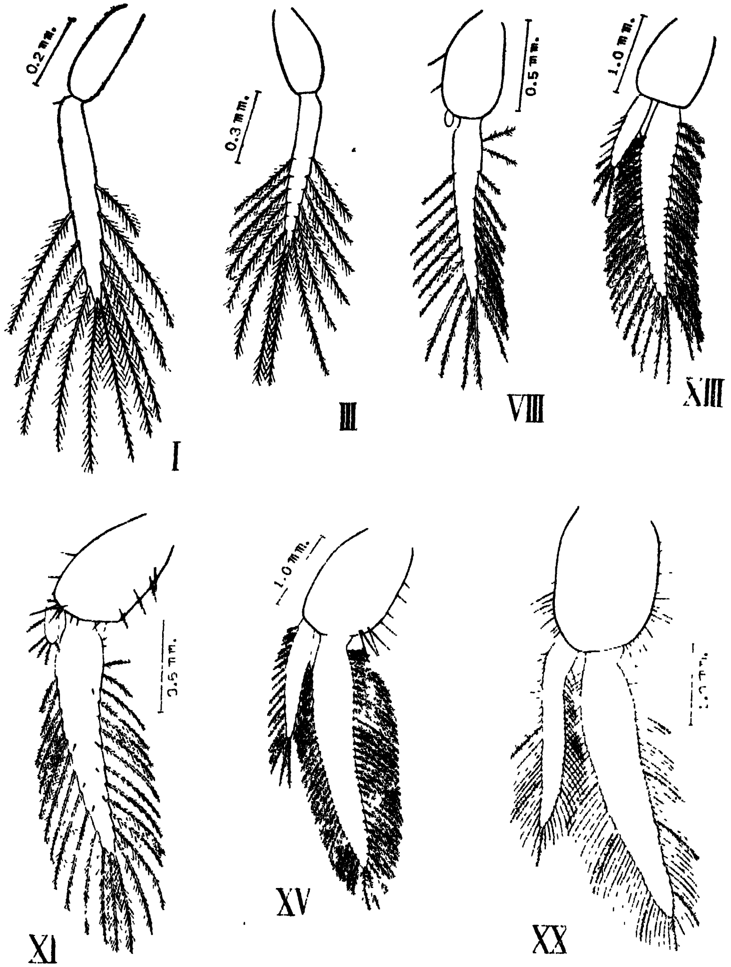

Fig. 30. 2nd pleopod in post-larval stage. Roman numerals shows number of substages.

Branchial Formation: — Although something was touched on the formation of the gills in describing the development of appendages, the matter is briefly summarized here again for convenience (See Table 15).

The arthrobranchia which appears one each on the 3rd maxillipede and the following 3 pairs of pereiopods in the 1st mysis, is yet very tiny and often scarcely visible, an additional tiny arthrobranchia appearing on these appendages upon reaching the 2nd mysis. Besides these arthrobranchiae a mastigobranchia appears on the 1st and 2nd maxillipedes in the 2nd mysis. The arthrobranchiae that appeared in the preceding substage becomes slightly larger in the 3rd mysis, while a tiny arthrobranchia appears also on the 4th pereiopod.

Table 15

The branchial formula

mp, maxillipede; pr, pereiopod; r, rudiment

Appendage	mp 1				mp-2				mp-3				pr-1				pr-2				pr-3				pr-4				pr 5			
Branchiae / Substage	Mastigobranchia	Podobranchia	Arthrobranchia	Pleurobranchia	Mastigobranchia	Podobranchia	Arthrobranchia	Pleurobranchia	Mastigobranchia	Podobranchia	Arthrobranchia	Pleurobranchia	Mastigobranchia	Podobranchia	Arthrobranchia	Pleurobranchia	Mastigobranchia	Podobranchia	Arthrobranchia	Pleurobranchia	Mastigobranchia	Podobranchia	Arthrobranchia	Pleurobranchia	Mastigobranchia	Podobranchia	Arthrobranchia	Pleurobranchia	Mastigobranchia	Podobranchia	Arthrobranchia	Pleurobranchia
1st mysis	—	—	—	—	—	—	—	—	—	—	r	—	—	—	r	—	—	—	r	—	—	—	r	—	—	—	—	—	—	—	—	—
2nd ,,	1	—	—	—	1	—	—	—	—	—	1+r	—	—	—	1+r	—	—	—	1+r	—	—	—	1+r	—	—	—	—	—	—	—	—	—
3rd ,,	1	—	—	—	1	—	—	—	—	—	2	—	—	—	2	—	—	—	2	—	—	—	2	—	—	—	r	—	—	—	—	—
1st post larva	1	—	—	—	1	—	—	—	—	—	2	—	—	—	2	—	—	—	2	—	—	—	2	—	—	—	1	—	—	—	—	—
2nd ,,	1	—	—	—	1	1	1	—	—	—	2	—	—	—	2	—	—	—	2	—	—	—	2	—	—	—	1	—	—	—	—	—
3rd ,,	1	—	—	—	1	1	1	—	—	—	2	—	—	—	2	—	—	—	2	—	—	—	2	—	—	—	1	—	—	—	—	—
4th ,,	1	—	—	—	1	1	1	—	—	—	2	1	—	—	2	1	—	—	2	1	—	—	2	1	—	—	1	—	—	—	—	—
5th ,,	1	—	—	—	1	1	1	—	—	—	2	1	—	—	2	1	—	—	2	1	—	—	2	1	—	—	1	—	—	—	—	—
6th ,,	1	—	—	—	1	1	1	—	—	—	2	1	1	—	2	1	1	—	2	1	1	—	2	1	—	—	1	1	—	—	—	—
7th ,,	—	—	—	—	1	1	2	—	—	—	2	1	1	—	2	1	1	—	2	1	1	—	2	1	—	—	1	1	—	—	—	—
8th ,,	1	—	—	—	1	1	2	—	—	—	2	1	1	—	2	1	—	—	2	1	1	—	2	1	—	—	1	1	—	—	—	1
9th ,,	1	—	—	—	1	1	2	—	—	—	2	1	1	—	2	1	1	—	2	1	1	—	2	1	—	—	1	1	—	—	—	1
10th ,,	1	—	—	—	1	1	2	—	—	—	2	1	1	—	2	1	1	—	2	1	1	—	2	1	—	—	1	—	—	—	—	1
11th ,,	1	—	—	—	1	1	2	—	1	—	2	1	1	—	2	1	1	—	2	1	1	—	2	1	—	—	1	1	—	—	—	1
adult	1	—	—	—	1	1	2	—	1	—	2	1	1	—	2	1	1	—	2	1	1	—	2	1	—	—	1	1	—	—	—	1

There are the same number of gills in the 1st post-larva as in the 3rd mysis no new gills appearing in this substage, the gills that appeared in the preceding stage becoming distinct. A podobranchia and an arthrobranchia appear on the 2nd maxillipede in the 2nd post-larva. Only the 2nd maxillipede has a podobranchia, the last-named never appearing on the other appendages. No new gills appear in the 3rd post-larva. One pleurobranchia each appears on the 3rd maxillipede and on the successive 3 pairs of pereiopods upon reaching the 4th post-larva. In the 6th post-larva one mastigobranchia each appears on the first 3 pereiopods and one pleurobranchia on the 4th pereiopod. An additional arthrobranchia appears on the 2nd maxillipede in the 7 post-larva. One pleurobranchia appears on the 5th pereiopod in the 8th post-larva. In the 11th post-larva one mastigobranchia appears on the 3rd maxillipede. The number of gills in the 11th post-larva becomes the same as that in the adult prawn.

IV. Rearing

i. *Egg*

Since this prawn spawns at night, as described in the previous chapter, its eggs must be gathered during the night. As already mentioned, a prawn 20 cm long spawns approximately 700,000 eggs, which, however, are the number in the ovary removed when the eggs become separated in it as the result of the melting of their germinal vesicles before spawning. To gather all the eggs that have been spawned in the breeding pond is an impossibility. The writer could obtain from a single prawn from 100,000 to 200,000 eggs.

Approximately 10,000 of these gathered eggs are placed in a cylindrical glass receptacle of 20 cm diameter and 15 cm deep, filled with sea-water that has been carefully filtered in a filter-bucket containing layers of charcoal, sand and pebbles. Any large quantity of refuse in the sea-water will deposit on the bottom of the vessel and conglutinate the egg-surface, interfering with the hatching. Although it is necessary to purify the sea-water for breeding nauplius, zoea and mysis, filtration may be dispensed with when they reach the post-larval stage. With this method, the eggs hatch in the glass receptacle above mentioned in from 13 to 14 hours, the water-temperature being from 27° to 29°C. There is no necessity for changing the sea-water or stirring it during this period.

Relation between Salinity and Hatch-Percentage: In order to study the relation between salinity and the hatch-percentage of the eggs, the writer bred some selected eggs in sea-water of various salinities. The receptacle for this purpose was a glass cylinder 13 cm diameter and 10 cm deep containing sea-water. Well-water was added to the sea-water when low salinity was required, while coarse salt was added to the sea-water when a high salinity was desired. The eggs used for the experiments were from the 8-cell stage to the morula. 200 eggs were placed in each receptacle.

From the experimental result given in Table 16 and Fig. 31, incubation is possible when the salinity is 23.0‰, but larvae hatched in water of this salinity are so weak that they are unable to swim, all dying after a lapse of 2 hours. Larvae hatched in water of 26‰ salinity are also fairly weak, although they swim towards the light. They too gradually weakened and the majority died after a lapse of 30 hours with scarcely any of them passing into zoea. Larvae hatched in water of over 27‰ salinity being robust, the majority of them pass into zoea, but if the salinity exceeds 39‰ the hatch-percentage gradually drops, and when it reaches 44‰, hatching stops entirely. Although the percentage of hatch drops with high salinity, the hatched larvae are strong and do not die. The most suitable salinity for hatching the eggs lies between 27 and 39‰.

Hatch-Percentage of Egg Selected at Random: -- The writer selected 1,000 eggs at random from those that were spawned by a single prawn and counted the number that hatched with the object of arriving at the percentage of hatch. The result of 20 such counts will be seen from Table 17. The receptacle

Table 16

Relation of survival percentage of the eggs to salinity, incubated for 15 hours

Water temp. 26.5°C 28.3°C

No.	Salinity ‰	Eggs (beginning)	1st nauplius (end)	%
1	16.0	200	0	0
2	19.0	,,	0	0
3	23.0	,,	126	63.0
4	26.0	,,	137	68.5
5	27.0	,,	136	68.0
6	29.0	,,	143	71.5
7	32.0	,,	179	89.5
8	33.0	,,	190	95.0
9	35.0	,,	176	88.0
10	37.0	,,	151	75.5
11	39.0	,,	115	57.5
12	41.2	,,	55	27.5
13	42.5	,,	47	23.5
14	43.0	,,	19	9.5
15	44.0	,,	0	0
16	45.6	,,	0	0

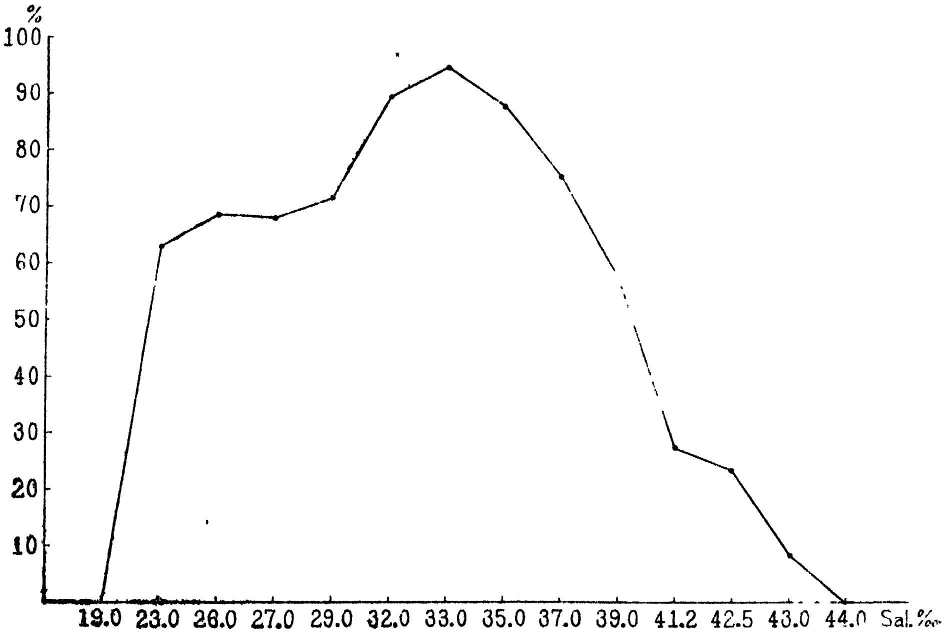

Fig. 31. Survival percentage of eggs in relation to salinity, incubated for 15 hours, water temperature 26.5°C–28.3°C.

Table 17

Survival percentage of the eggs reared for 18 hours

No	Eggs (beginning)	1st nauplius end	%	Salinity ‰	Water temp. °C
1	1,000	769	76.9	29.04	27.0–28.5
2	.	654	65.4	29.52	26.5 28.0
3	,,	699	69.9	28.75	27.5 28.5
4	,,	775	77.5	30.86	27.0 28.1
5	,,	907	90.7	30.59	27.0 29.0
6	,,	901	90.1	30.59	26.5 28.0
7	,,	629	62.9	31.60	27.0 28.5
8	,,	703	70.3	27.19	25.0 27.0
9	,,	780	78.0	27.19	25.5 26.0
10	,,	812	81.2	29.90	26.8 27.5
11	,,	540	54.0	30.68	26.6-28.0
12	,,	668	66.8	31.10	27.2 28.5
13	,,	775	77.5	30.96	27.0 29.0
14	,,	780	78.0	30.88	26.0 27.0
15	,,	198	19.8	32.15	27.4 29.0
16	,,	552	55.2	31.15	27.1 29.0
17	,,	838	83.8	33.02	26.5 27.5
18		530	53.0	32.88	26.5 28.0
19	,,	933	93.3	32.18	27.1–28.5
20	,,	388	38.3	32.40	26.5 27.5
Total and average	20,000	14.131	70.6	30.68	26.7 28.0

used was the same as that just described. The lowest salinity was 27.19‰ and the highest 33.02‰, these being quite similar to the salinity of their natural habitat along the coast of the Inland Sea. The lowest percentage of hatch was 38.8 and the highest 90.7, but on the whole from 70 to 80. The highest hatch percentage exceeded twice that of the lowest. In this case, the two salinities were both higher than 30‰ showing that difference in salinity is not correlated with difference in hatch-percentages. Since the eggs for test were selected at random from a very large number with the contingency that the selection may have inadvertently comprised a large number of eggs that were suited for hatching and *vice versa*. The main reason, however, lies in differences in the methods of spawning eggs and in the hardiness or weakness of the adult prawns. When a strong prawn spawns its eggs while in the act of swimming, the percentage of hatch is large, but when a weak prawn spawns its eggs by moving its pleopods on the sea-bottom without swimming, the percentage of hatched eggs is small.

ii. *Nauplius*

As already mentioned, breeding is comparatively easy in the nauplius stage, since the yolk is contained in the body. The writer always breeds the nauplius that have hatched from the eggs in the same receptacle and the sea-water that were used in hatching the eggs always ensured good results.

Relation between Salinity and Nauplius: - As in the case of eggs, when studying the relation between nauplius and salinity, the writer added well-water into sea-water in order to lower the salinity and added coarse salt in order to raise, which method was also used in studying the relation between salinity and mysis, and between salinity and post-larvae. The receptacle used was a glass cylinder, 15 cm dia. and 15 cm deep. 200 1st nauplius were bred in each glass receptacle and removed them from the receptacles as soon as they became the 1st zoea, and counted them. As will be seen from Table 18 and Fig. 32, the experiments showed that none became 1st zoea in water of less than 23‰ salinity; a few became 1st zoea in water of 26‰. In 23‰, all the nauplius died without undergoing a single ecdysis, whereas in 26‰ the majority of them died after 3 or 4 ecdyses. Nauplius suddenly regained their strength in water of over 27‰, the majority passing into 1st zoea. Very satisfactory results were obtained in water of high salinity up to 39‰, but above 40‰ condition suddenly changed for the worse, only a few passing into

Table 18

Relation between salinity and nauplius reared for 38 hours

Water-temp. 25.8°C-29.5°C

No.	Salinity ‰	1st nauplius (beginning)	1st zoea (end)	%
1	16.0	200	0	0
2	19.0	,,	0	0
3	23.0	,,	0	0
4	26.0	,,	3	1.5
5	27.0	,,	182	90.5
6	29.0	,,	153	76.5
7	32.0	,,	198	99.0
8	33.0	,,	191	95.0
9	35.0	,,	181	90.5
10	37.0	,,	190	95.0
11	39.0	,,	184	92.0
12	40.2	,,	6	3.0
13	41.2	,,	6	3.0
14	42.5	,,	0	0
15	43.0	,,	0	0

1st zoea, while the majority died after 3 or 4 ecdyses. In water exceeding 42‰, none passed into 1st zoea, all dying after 1 or 2 ecdyses. The best salinity for nauplius is from 27 to 39‰.

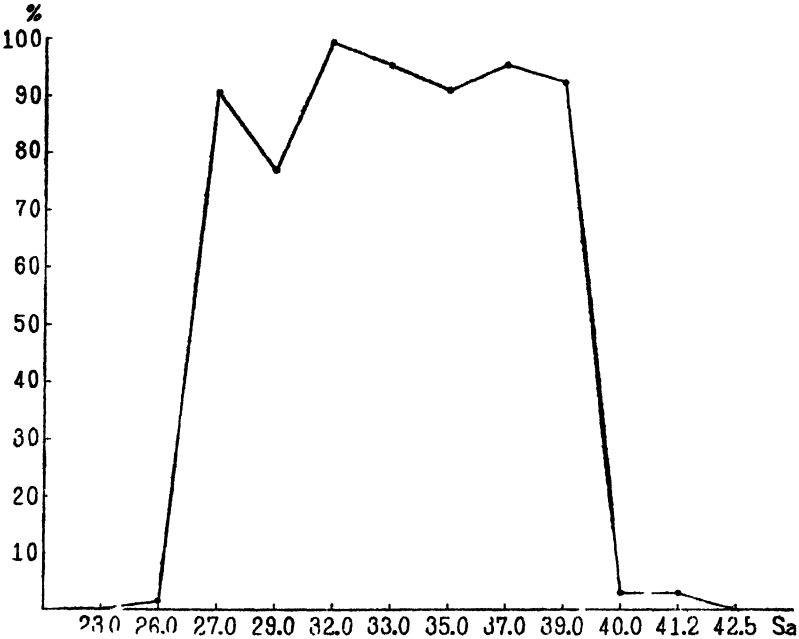

Fig 32 Relation of salinity to nauplius reared for 38 hours, water temperature 25.8°C–29.5°C

Survival Percentage of Nauplius: — The percentage of nauplius that become 1st zoea after breeding from the 1st nauplius, the writer will call the survival percentage of nauplius. The result of 20 experiments is shown in Table 19, from which it will be seen that the lowest of these survivals is 68.3% and the highest, 99.5%. There are 6 intermediate survivals of from 80% to 90%, and 13 over 90%. The viability of nauplius can easily be imagined from the above facts.

Relation between Nauplius and Water-Temperature: – In the absence of a thermostat in the rather ill-equipped experimental laboratory that we had set up on the coast, it was not possible to make our investigations of the relation between water-temperature and the larvae very accurately. When it was desired to either raise or lower the temperature of the water in the glass receptacle, hot water or ice water, as the case may be, was applied outside of the receptacle. The glass receptacle used was a çylinder 15 cm dia. and 15 cm deep. The larvae used were 1st, 3rd and 6th nauplius, but as the same results were obtained with all of them, the writer will deal only with the 3rd nauplius.

The resistance of nauplius to water of low temperature, as shown in Table 20, was very great down to 15°C, the larvae swimming about the surface of the water. At 13°C their movements became less energetic. At water-temperature below 10°C, all the larvae sank to the bottom of the receptacle moving only their appendages. At temperature below 8°C, the majority fell into a syncopic state, with only few moving their appendages; at below 7.5°C they all fell into the same state, and all died after a lapse of over 3 hours.

Table 19

Survival percentage of nauplius reared for 40 hours

No.	1st nauplius (beginning)	1st zoea (end)	%	Salinity ‰	Water temp. °C
1	261	242	92.7	27.16	26.0-29.0
2	700	689	98.4	29.04	26.9-29.0
3	600	597	99.5	29.52	25.7-27.8
4	600	596	99.5	28.75	25.6-28.3
5	700	649	92.7	30.86	25.4-26.8
6	900	893	99.2	30.59	26.7-27.3
7	600	538	89.7	31.60	24.6-27.2
8	700	695	99.2	27.19	26.4-27.4
9	800	783	98.0	27.19	26.3-27.4
10	800	711	88.9	29.90	27.1-27.3
11	540	476	88.1	30.68	27.3-27.7
12	775	701	90.5	30.96	27.1-29.8
13	498	493	99.0	32.45	26.1-27.4
14	552	506	91.7	31.13	26.7-28.6
15	530	515	97.2	32.88	27.1-29.1
16	933	883	94.6	27.40	27.3-29.7
17	388	338	87.1	32.40	27.5-28.5
18	838	572	68.3	33.02	27.1-28.6
19	200	179	89.5	32.50	28.7-29.6
20	114	98	86.0	27.10	27.6-30.9
Total and average	12,029	11,159	92.7	30.11	26.6-28.4

The resistance of larvae to high water-temperature, as will be seen from Table 21, was very satisfactory up to 34°C, when most of them were seen swimming on the surface, but around 36°C, although they moved their appendages briskly, they became somewhat less active, most of them swimming in mid-depth, with only a few swimming on the surface. Above 38°C, the majority swam at lower depth, while some of them frequently fell into a state of syncope, whereas after a lapse of over 30 minutes, most of them fell into a syncopic state, and all were dead after 2 hours.

From these experiments, it was found that the most suitable water-temperature for nauplius life is from 15° to 34°C.

Table 20

Relation between 3rd nauplius and low water-temperature

Salinity, 30.5‰, 30 specimens examined.

Time elapsed hr.	min.	Water temp. °C	Remarks
	0	25.5	All larvae swim vigourously in upper layer.
	30	20.2	
1	00	18.2	
1	30	15.0	
2	00	13.0	Movement of appendages, somewhat sluggish, but many larvae swim in upper layer.
2	30	11.0	Some larvae swim in lower layer, but most of them in upper and middle layer.
3	00	11.0	
3	30	11.2	Many larvae swim in lower layer; only few in upper and middle layer.
4	00	9.2	All larvae sink to the bottom and feebly move their appendages.
4	30	9.0	,,
5	00	7.9	Most asphyxial, and a very few move their appendages feebly.
5	30	7.5	All asphyxial.

Table 21

Relation between 3rd nauplius and high water-temperature

Salinity, 30.5‰, 30 specimens examined.

Time elapsed hr.	min.	Water temp. °C	Remarks
	0	24.0	All larvae swim actively in upper layer.
	30	28.0	
1	00	29.5	
1	30	31.2	
2	00	33.0	
2	30	34.0	
3	00	35.9	All larvae move appendages rapidly, but most of them swim in middle layer, a few only in the upper.
3	30	36.3	,,
4	00	37.2	Most swim in middle and lower layer, none in upper.
4	30	38.3	Most swim in lower layer, some are asphyxial.
5	00	38.5	All larvae asphyxial.

iii. *Zoea*

The yolk which was in the body is entirely absorbed during that period when the larva passes from 6th nauplius to 1st zoea. The larvae, which at the period of transformation are fairly robust, weaken considerably after lapse of 1 day and night. If proper food in substantial amounts is not given them, the majority of them die before passing into 2nd zoea. Breeding larvae of this prawn is the most difficult in the zoea stage. Heldt (1939) succeeded in enabling 15 moults of *P. trisulcatus* by daily supplies of copepoda, which she gathered for feeding the zoea. She, however, bred only a few zoea for experimental purposes and did not succeed in breeding any large number of them. If it is a matter of breeding only a small number of zoea for experimental purposes, passage into mysis can be satisfactorily accomplished by giving the nauplius of this prawn itself. The zoea, however, seems to lack the initiative for searching for its own food, only eating whatever food comes on its way while swimming in the upper and middle depths, and it dies eventually if there is no food in the vicinity. Its food, therefore, must be of a kind that will always float in the water.

A large quantity of food must always be placed in the receptacle if one is to breed large number of zoea in a small receptacle. From the writer's experience, he believes that diatoms are the food that best meets this requirement, so that they should be cultured at hand as the source of food; no other methods have here so far availed.

Allen and Nelson (1902) have given 18 species of diatoms that could be reared; the number including *Skeletomema costatum* and *Nitzschia closterium.* These 2 species of diatoms were found in the writer's experiments to be the ideal food for zoea of this prawn, particularly the former. Besides *P. japonicus*, the writer reared the zoea of *P. affinis* and *P. monoceros* on *Sk. costatum* with good results.

The writer is greatly indebted to Mr. Yosiyuki Matue for valuable information in regard to the rearing of *Sk. costatum.* The cell size of *Sk. costatum* in the open sea ranges from 10 to 20 μ. By selecting the tiniest cells and rearing them in a culture flask, it may be seen that they gradually diminish in size until after a lapse of 6 months or 1 year their size drops down to from 5 to 7 μ. *Sk. costatum* thus reduced in size is excellent food for zoea. The culture fluid is Miquel's solution modified by Mr. Matue, as follows:

A. KNO_3....4.04 gr to be dissolved in 100 cc of water and stored after boiling once.

B. $Na_2HPO_4 12H_2O$....0.4 gr to be dissolved in 100 cc of water and stored after boiling once.

C. K_2SiO_3....0.8 gr to be dissolved in 100 cc of water and stored after boiling once.

D. Refined Agar-Agar....1.0 gr to be dissolved in 100 cc of water and heated before use.

E. $FeCl_3$....A drop to be dissolved in 20 cc of water. Only fresh material to be used.

The above solutions are added to one liter of sea-water in the proportion of 10 cc each of A, B and D, 3 cc of C and 1 cc of E. The whole after once boiled is to be left to stand for 2 days and nights, after which it is ready for use. When for rearing *Sk. costatum*, a volume of 500 cc of this culture solution is placed in a one-liter culture flask. Since *Sk. costatum* is weak in strong light, direct sun rays should be avoided. The flask should be placed near the window facing north for the regular exposure to weak sunlight throughout the day.

3 days after adding 2 or 3 drops of diatom culture to a flask containing this solution at a water-temperature of from 27° to 29°C the diatoms will flourish to such an extent as to impart a light brown colour to the water in the flask. The number of the cell of *Sk. costatum* is then about 3×10^7 per liter. With further multiplication, when the water then turns a dark brown, its number is $6 \sim 9 \times 10^9$ per liter.

By this means cultivated diatoms are added daily in suitable quantity to the receptacle in which the zoea are reared. A glass cylinder, 20 cm dia. and 30 cm deep, was used for breeding the zoea. Approximately 3,000 zoea were put into one glass receptacle. Upon giving them sufficient diatoms at a water-temperature of from 27° to 29°C, after 3 ecdysis the 1st zoea will pass into a 1st mysis after about 5 days.

There is no need for changing the water during this period. In breeding zoea, Heldt (1939) always changed a fixed quantity of water in the tube every day in order to keep it fresh. According to Pearson (1939), who was unable to change the water owing to his experimental laboratory not being yet in full working order, breeding of zoea was impossible. The writer thinks, however, that if suitable quantity of food are given, there is no need to change the water or to stir it.

Although, as in nauplius, larvae in the zoea stage have a tendency to move in the direction of light, strong light should be avoided, because the zoea will sink to the bottom of the receptacle and die, should the direct rays of the sun strike the side of the receptacle.

Relation between Zoea and Salinity: — The receptacle used in this experiment was a glass cylinder 15 cm dia. and 20 cm deep, and the food *Sk. costatum*. The experiments showed (See Table 22 and Fig. 33), that they all died in water of salinity lower than 26.3‰ and that the 1st zoea survived to become 1st mysis in water of 27.3‰ salinity for the first time. Salinity from 31 to 32‰ was suitable, but they all died if it exceeded 36‰, so that the salinity at which the 1st zoea passed into 1st mysis after 3 ecdyses was from 27 to 35‰.

Compared with the case of the nauplius stage, the salinity limits are narrowed. Larvae did not undergo a single ecdysis in water lower than 26‰, and died after a single ecdysis with 36‰. Not a single ecdysis was possible in water higher than 38‰.

Survival Percentage of Zoea: — The survival percentage of zoea is the percentage of the number of larvae that pass into 1st mysis after being bred from the 1st zoea. The culture receptacles were glass cylinders 15 cm dia. and 25 cm deep. The results of 20 repeated experiments (Table 23) showed that

Table 22

Relation between salinity and zoea fed on diatoms for 6 days

Water-temp. 25.0°C–29.7°C.

No.	Salinity ‰	1st zoea (beginning)	1st mysis (end)	%
1	25.4	200	0	0
2	26.3	,,	0	0
3	27.3	,,	19	9.5
4	28.3	,,	2	1.0
5	29.1	,,	9	4.5
6	30.2	,,	17	8.5
7	31.2	,,	36	18.0
8	32.1	,,	41	20.5
9	33.0	,,	7	3.5
10	34.1	,,	13	6.5
11	35.0	,,	5	2.5
12	36.0	,,	0	0
13	37.1	,,	0	0
14	38.1	,,	0	0

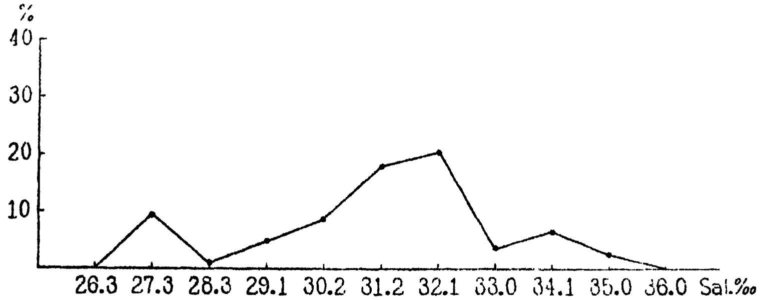

Fig. 33. Relation of salinity to zoea fed on diatoms for 6 days, water temperature 25°C–29.7°C.

the highest survival percentage was 64.6, the lowest 7.5, and the average percentage 27.9. Of the 20 repeated experiments, percentages of from 10 to 20 outnumbered all others with 5 times, followed by those of from 30 to 40 with 4 times, and those under 10 and between 20 and 30 with 3 times each. Of percentages of from 40 to 50, there were twice, those between 50 to 60 and 60 to 70 once each, but not a single survival percentage of over 70. The writer's numerous difficulties for many years encountered in breeding zoea, culminated in success, as shown in Table 23 -- results that he sees no possibilities of bettering at present.

Table 23

Survival percentage of zoea fed on diatoms for 6 days

No.	1st zoea (beginning)	1st mysis (end)	%	Salinity ‰	Water temp. °C
1	133	39	29.3	—	—
2	400	43	10.8	27.16	26.1-28.3
3	600	288	48.0	29.04	25.7-28.5
4	600	314	52.3	28.75	25.6-27.3
5	600	388	64.6	30.86	25.8-27.8
6	400	22	5.4	30.59	24.5-27.1
7	900	315	35.0	30.59	24.6-27.1
8	300	36	12.0	31.60	24.8-26.9
9	800	96	12.0	27.19	27.0-27.8
10	476	40	8.4	30.68	27.7-28.9
11	400	30	7.5	31.40	26.2-29 2
12	500	99	19.8	—	26.7-29.3
13	200	65	32.8	32.50	26.7-29.0
14	500	242	48.4	32.45	26.6-28.5
15	500	129	25.8	31.13	26.7-29.2
16	500	133	26.6	32.88	26.5-29.1
17	883	186	21.2	32.48	24.0-27.7
18	500	71	14.2	—	22.8 26.2
19	500	155	31.0	—	22.8-27.6
20	500	161	32.2	—	—
Total and average	10,192	2,852	27.9	30.60	26.0-28.0

Relation between Zoea and Water Temperature: — The breeding receptacle was a glass cylinder 15 cm dia. and 15 cm deep, in which 30 specimens of 1st zoea were placed. The experiments using the 2nd and 3rd zoea were almost the same as that with the 1st. The resistance to low water-temperature, as will be seen from Table 24, was rather feeble at 14°C, some larvae sinking to the bottom. They all sank to the bottom at 11°C, where they only feebly moved their appendages while some fell into a syncope, into which state they all fell at 8.5°C in over 3 hours, after then at the same temperature they all died.

Their resistance to high water-temperature will be seen from Table 25. They were energetic at 33°C, swimming at upper depth, whereas at 34.2°C, their movements were so brisk, and their appendages worked so hard as to be abnormal. At 39°C most of them fell into a syncopic state and died after a lapse of over 1 hour in the same water-temperature. From these experiments, the most suitable water-temperature for the raising of the 1st zoea is conjectured from 15° to 33°C.

Table 24

Relation between the 1st zoea and low water-temperature

Salinity 30.0‰, 30 specimens examined.

Time elapsed		Water temp.	Remarks
hr.	min.	°C	
	0	25.5	All larvae swim vigorously in upper layer
	30	21.0	
1	00	19.5	
1	30	18.0	
2	00	16.5	
2	30	15.0	
3	00	14.1	Movements of appendages are somewhat sluggish, some larvae sink to bottom.
3	30	13.5	Most of them sink to bottom and move appendages faintly, few of them swim in middle layer.
4	00	12.5	
4	30	11.0	All sink to bottom and move appendages only faintly, some of them asphyxial.
5	00	10.4	
5	30	8.5	All larvae asphyxial.

Table 25

Relation between 1st zoea and high water temperature

Salinity, 30.5‰, 30 specimens examined.

Time elapsed		Water temp.	Remarks
hr.	min.	°C	
	0	24.5	All larvae swim actively in upper layer.
	30	25.9	
1	00	29.8	
1	30	30.5	
2	00	32.0	
2	30	33.5	
3	00	34.2	All swim in upper layer, but movements of appendages so rapid that they seem to be abnormal.
3	30	35.2	Some swim in middle and lower layer.
4	00	37.3	Most sink and creep on bottom, and a few lying on bottom move their appendages convulsively.
4	30	39.0	Most asphyxial.
5	00	39.2	

iv. *Mysis*

Although, as already mentioned, rearing of the zoea stage is very difficult, yet with ecdysis of the 3rd zoea and its passage into the mysis stage the creature suddenly gets strong making its rearing easier. As to its food, although it may be bred on the previously mentioned diatoms alone, additional good results can be obtained by mixing nauplius of the prawn with the diatoms. See and compare Tables 27 and 28. A glass cylinder is also suitable for breeding in the mysis stage.

As will be obvious on examining the structure of the appendages, the various refuse in the water are very liable to attach themselves to the body in the zoea stage. As the refuse being one of the causes of their death, a deeper breeding receptacle is recommended and precautions must be taken to see that only the smallest possible number of larvae sink to the bottom. Upon their attaining the mysis stage, however, the shortening of their appendages diminishes the risk of their dying through fouling themselves with refuse whenever they sink to the bottom. There is then no need of bothering about the depth of the receptacle. In the zoea stage particularly the chief difficulty is the food problem when one wishes to raise the larvae, whence for larvae in stages other than zoea, it may be said that there is scarcely any need for special methods of feeding.

Relations between Mysis and Salinity: The writer has bred 10 1st mysis, each in breeding receptacles consisting of a glass cylinder 12 cm dia. and 15 cm deep using for food a mixture of *Sk. costatum* and the nauplius of the prawn

Table 26

Relation between salinity and mysis, fed on diatoms and nauplius for 6 days

Water temp 25.5°–29.5°C

No	Salinity ‰	1st mysis beginning)	1st post larvae (end)	%
1	19.0	10	0	0
2	23.0	,,	10	100
3	26.0		10	100
4	29.0	,,	10	100
5	32.0	,,	10	100
6	33.0	,,	10	100
7	39.3	,,	10	100
8	40.2	,,	10	100
9	42.5	,,	10	100
10	44.0	,,	10	100
11	50.1	,,	4	40
12	53.0	,,	2	20
13	54.0	,,	0	0

itself. The experiments showed (See Table 26, Fig. 34) that they all passed into 1st post-larva in water having salinity of from 23 to 44.0‰. In that of 19‰ they all died without any ecdysis. In water of 50‰, only 4 out of the 10 1st mysis passed into 1st post-larva, while in that of 53‰, only 2 passed into 1st post-larva. At 54‰ they all died without undergoing a single ecdysis. Therefore, waters with salinity of from 23 to 14‰ are best suited for mysis. This is a fairly wide range compared with that for the zoea stage.

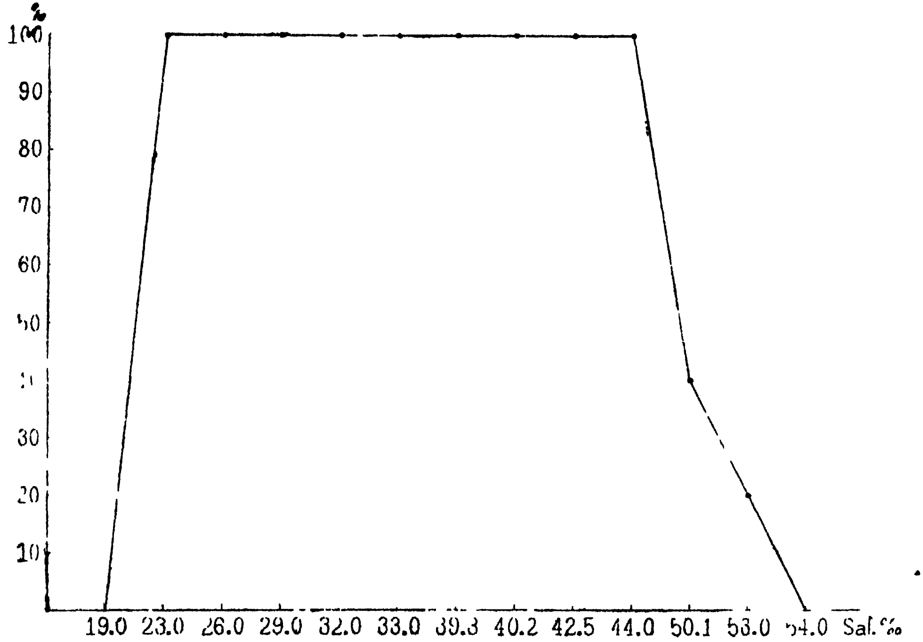

Fig 34. Relation of salinity to mysis fed on diatoms and prawn larvae for 6 days, water temperature 25.5°C 29.5°C.

Survival Percentage of Mysis: - The survival percentage of mysis is the percentage of the number of larvae that pass into 1st post-larvae after the 1st mysis. The breeding receptacles were glass cylinders of diameter 15 cm and depth 20 cm. Table 27 gives the results of feeding them solely on *Sk. costatum*. The highest percentage was 94.9 and the lowest 33.3, the average being 19.3. As will be seen from Table 27, the survival percentage varies. Table 28 gives the results of feeding them with *Sk. costatum* and the nauplius of this prawn, by which the highest percentage was 99, lowest 66, with an average of 86.5. These survival percentages were almost constant.

Relation between Mysis and Water-Temperature: — The writer experimented by putting 1st mysis in a glass breeding receptacle, 12 cm dia. and 10 cm deep. The resistance of both 2nd and 3rd mysis to water-temperature was about the same as that of the 1st mysis.

The resistance to low water-temperature, as shown in Table 29, was very

Table 27

Survival percentage of mysis fed on diatoms alone for 6 days

No.	1st mysis (beginning)	1st post-larvae (end)	%	Salinity ‰	Water temp. °C
1	39	37	94.9		—
2	43	17	39.5	27.16	25.6-27.1
3	16	15	93.7	27.16	25.6-26.8
4	300	190	63.3	29.04	25.7-25.9
5	314	104	33.5	28.75	26.2-28.3
6	388	184	47.4	30.86	24.8-25.2
7	22	17	77.3	30.59	25.5-26.8
8	315	141	44.8	30.59	25.3-27.1
9	36	29	80.6	31.60	25.4-26.8
10	30	12	40.0	27.19	27.8-30.0
11	96	50	52.1	27.19	27.0-29.7
12	155	110	71.0	30.68	26.0-28.5
13	30	12	40.0	31.40	27.4-31.9
14	99	40	40.4	--	26.7-28.5
15	65	24	36.9	32.50	26.7-27.9
16	242	110	45.4	32.45	26.9-29.2
17	129	43	33.3	31.13	26.9-27.9
18	25	11	44.0	30.02	24.0-28.1
19	133	50	37.6	32.88	22.8-26.3
20	186	119	64.0	32.48	22.7-26.9
Total and average	2,663	1,315	49.3	30.20	24.3-27.8

Table 28

Survival percentage of mysis fed on diatoms and nauplius for 6 days

No.	1st mysis (beginning)	1st post-larvae (end)	%	Salinity ‰	Water temp. °C
1	100	93	93.0	29.12	25.1-27.1
2	„	90	90.0	30.15	23.1-26.2
3	„	86	86.0	30.15	24.0-27.0
4	„	66	66.0	30.15	26.0-29.0
5	„	70	70.0	28.12	28.3-29.7
6	„	99	99.0	28.12	24.5-26.8
7	„	90	90.0	28.12	27.5-29.0
8	„	76	76.0	31.05	26.9-29.5
9	„	97	97.0	31.05	27.1-28.3
10	„	98	98.0	31.05	26.4-28.5
Total and average	1,000	865	86.5	29.70	25.8-28.1

strong up to 14°C, with a few showing feeble movements at 13°C. Below 8°C they ceased to move their appendages, all falling into a state of syncope and dying after a lapse of over 3 hours the temperature remaining unchanged.

Table 29

Relation between 1st mysis and low water-temperature

Salinity, 29.5‰, 30 specimens examined.

Time elapsed		Water temp.	Remarks
hr.	min.	°C	
	0	23.0	All larvae swim actively in all layers.
1	00	21.5	,,
1	30	18.5	,,
2	00	16.5	,,
2	30	14.5	,,
3	00	13.0	A few somewhat sluggish.
3	30	12.4	Most sink to bottom and feebly move appendages, very few swim.
4	00	9.4	All sink to bottom and move appendages feebly.
4	30	8.5	Some asphyxial
5	00	7.2	All asphyxial.

Up to 34.5°C, resistance to high water-temperature, as shown in Table 30, was stubborn, the creatures swimming about, while at 35°C some of them got somewhat lax in their movements, although the majority of them continued their active swimming. All larvae fell into a syncopic state at 38.8°C and died after a lapse of over 1 hour at the same water-temperature. From these ex-

Table 30

Relation between 1st mysis and high water temperature

Salinity, 29.5‰, 30 specimens examined.

Time elapsed		Water temp.	Notes
hr.	min.	°C	
	0	26.0	All larvae swim actively in all layers.
1	00	29.0	,,
1	30	31.5	,,
2	00	33.0	,,
2	30	34.5	,,
3	00	35.0	A few sink to bottom.
3	30	36.2	Most sink to bottom and move appendages feebly, very few swim.
4	00	37.5	All sink to bottom, some asphyxial.
4	30	38.8	All larvae asphyxial.

periments, it is found that the most suitable water-temperature for mysis is from 14° to 34°C.

v. *Post-larva*

Compared with the mysis stage, breeding of larvae is simple still further with passage of the 3rd mysis into 1st post-larvae. With this transformation, however, it is necessary to give them animal food, since they cannot be bred entirely on vegetable matter. If fed on vegetable matter alone, they will attack one another. It may be said that fish-meal or pieces of small fish finely crushed are delicacies for them. The writer discovered that they also relished water-flea (*Moina macrocopa*) bred in fresh water. It is a suitable food in the early stage of the post-larvae, since it is easily cultured. When feeding them with fish-meal, it is necessary to change the water in order to prevent it from putrefying, whereas there is no such necessity when giving them living water-fleas.

Although glass vessels are suitable for breeding until the mysis stage, larger receptacles are necessary to ensure sound post-larval development. The writer bred larvae upon passing into post-larvae for periods of 5 or 10 days in a concrete tank, 1 × 1.8 × 0.5 m built on land, while giving them water-fleas for food. Later, the writer bred them in a concrete tank, 2.5 × 5 × 1.2 m, built in sea-water, feeding them chiefly with fish-meal and pieces of crushed small fish. A water-gate was built in one section of the tank in order to permit free ingress and egress of sea-water with the ebb and flow of the tide. A wire gauze was fixed inside the water-gate in order to prevent the larvae from escaping and to make it impossible for small fishes, crabs and other enemies to steal into the tank. Sand 5 cm thick was laid over the bottom of the tank in order to serve as a bed for the larvae to creep into. Plate XVIII, Fig. 1 shows the tanks divided into 6 compartments that were constructed in the breeding pond. Larvae bred in these tanks.for a period of approximately 1 month grew to length from about 4 to 5 cm. Upon attaining this size they could safely breed in larger breeding ponds, since they were then able to escape from their enemies — small fishes and crabs. The writer bred them chiefly with small dead sardines putting them whole into the breeding pond.

Relations between Salinity and Post-larvae: — The breeding receptacle used was a glass cylinder, 15 cm diameter and 20 cm deep. 20 of the 1st post-larvae were placed in each receptacle and bred for a period of 8 days, and when the 1st post-larvae passed into the 3rd or the 4th, they were removed from the receptacle. Their food consisted of *Moina* and nauplius. In the experiments, their survival percentage exceeded 50 in water of from 23 to 47‰ salinity, as will be seen from Table 31 and Fig. 35. In water of as low a salinity as 22‰, their survival percentage fell to 25, and in water 20‰ to 10, while in water of only 19‰, they died without undergoing any ecdysis. In waters of higher salinity, the survival percentage fell to 40 in 48‰, and it suddenly dropped to 15 in water of 49‰, whereas they all died without a

Table 31

Relation between salinity and post-larvae, fed on nauplius and water-flea for 8 days

Water temp. 25.5°C–29.6°C.

No	Salinity	1st post-larvae (beginning)	3rd–4th post-larvae (end)	%
1	19.0	20	0	0
2	20.1	,,	2	10.0
3	22.1	,,	5	25.0
4	23.0	,,	12	60.0
5	24.1	,,	17	85.0
6	26.0	,,	11	55.0
7	28.1	,,	14	70.0
8	30.1	,,	16	90.0
9	35.0	,,	17	85.0
10	36.0	,,	18	90.0
11	38.0	,,	15	75.0
12	40.0	,,	16	80.0
13	43.0	,,	19	95.0
14	44.0	,,	14	70.0
15	46.0	,,	11	55.0
16	47.0	,,	15	75.0
17	48.0	,,	8	40.0
18	49.1	,,	3	15.0
19	50.1	,,	3	15.0
20	51.0	,,	2	10.0
21	52.0	,,	0	0

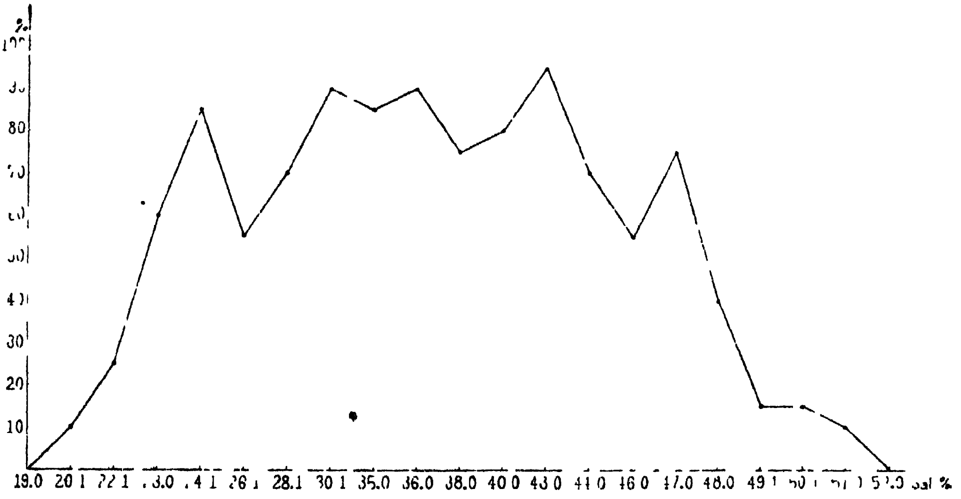

Fig. 35. Relation of post-larvae to salinity, fed on prawn larvae for 8 days, water temperature 25.5°C–29.6°C.

single ecdysis in 52‰. From these experiments, the most suitable salinity of water for post-larvae in their early stage is found to be from 23 to 47‰.

The suitable salinity for from eggs to post-larvae is shown in Table 32 and Fig. 36

Table 32

Most suitable salinity and water temperature for eggs and larvae

Stage	Eggs		Nauplius		Zoea		Mysis		1st–3rd post-larvae	
Salinity	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
‰	27	39	27	39	27	35	23	44	23	47
Water tem. °C			15	34	15	33	14	34	13	34

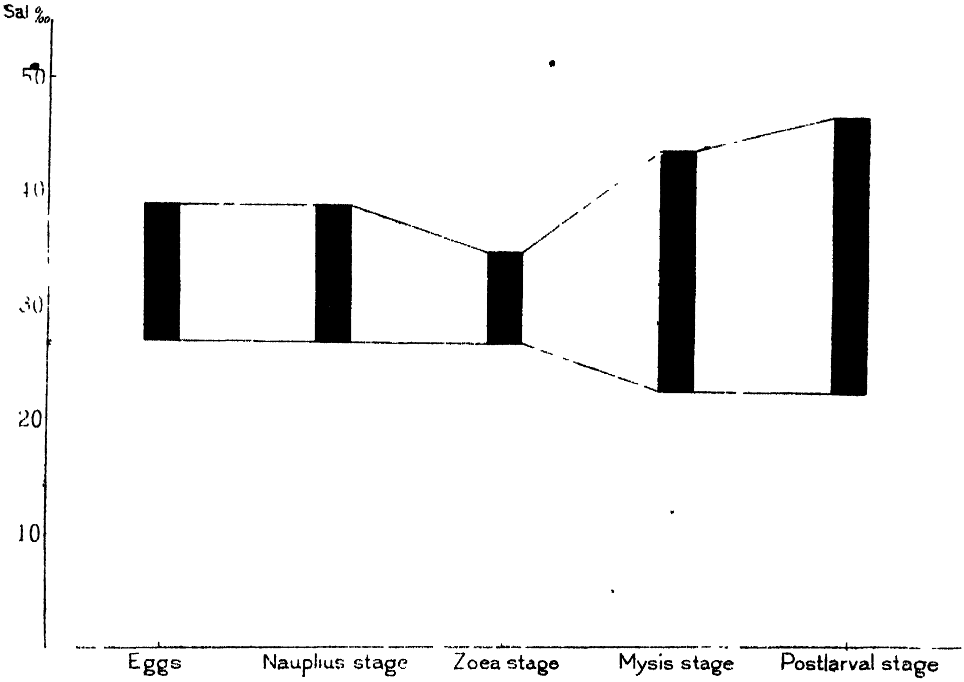

Fig. 36. Most suitable salinity for eggs and larvae.

Survival Percentage of Post-larvae: — By survival percentage of post-larvae is meant the percentage of the number of 1st post-larvae, after having been bred for a period of 12 days, that have passed into the 6th to 8th post-larvae. They were bred in a concrete tank built on land, as already described, their main food being fresh-water water-fleas, interspersed with fish-meal, and about $\frac{1}{3}$ of the water was changed every day.

As will be seen from Table 33, experiments showed that the survival percentage was very satisfactory with a maximum of 99.5, the minimum being 69.4 and the average 85.4. Of the 7 experiments, in 3 the survival percentage was above 90, in 2 from 80 to 90, with an experiment each of from 70 to 80 per cent and from 60 to 70 per cent.

Table 33

Survival percentage of post-larvae fed on fish-meal and water-fleas for 12 days

No.	1st post-larvae (beginnig)	6th-8th post-larvae (end)	%	Salinity ‰	Water temp. °C
1	549	416	75.7	30.28	25.0-28.0
2	1,501	1,042	69.4	29.15	26.1-29.2
3	446	444	99.5	31.14	24.4-27.8
4	1,042	965	92.6	30.17	26.5-28.4
5	4,215	3,475	82.4	29.50	25.4-29.3
6	3,520	3,115	88.4	30.16	26.5-28.4
7	3,122	2,854	91.4	28.15	24.5-27.3
Total and average	14,395	12,307	85.4	29.79	25.4-28.3

The survival percentages of eggs and larvae are shown in Table 34 and Fig. 37.

Table 34

Survival percentages of eggs and larvae

Stage	Eggs	Nauplius	Zoea	Mysis	Post-larvae
%	70.6	92.7	27.9	86.5	85.4

Relation between Post-larvae and Water-Temperatur: -- The glass breeding cylinder was 8 cm dia. and 5 cm deep. The writer experimented by putting 30 specimens of the 1st to 3rd post-larvae in this receptacle. Their resistance to low water-temperature, as shown in Table 35, was as follows. Signs of weakening among them were noticed at a water-temperature of 12°C. Most of them fell into a syncope at a temperature of 9°C, while they all fell into a like state at 7.5°C. After a lapse of 3 hours they all died at the same water-temperature.

Their resistance to high water-temperature, as given in Table 36, is as follows. Up to a water-temperature of 34°C, they all swam actively, showing signs of weakening at a temperature of 35°C. All fell into a syncope state at 39°C and died after a lapse of 1 hour in water at the same temperature. The above experiments show that the most suitable water-temperature for the 1st to 3rd post-larvae is from 13° to 34°C.

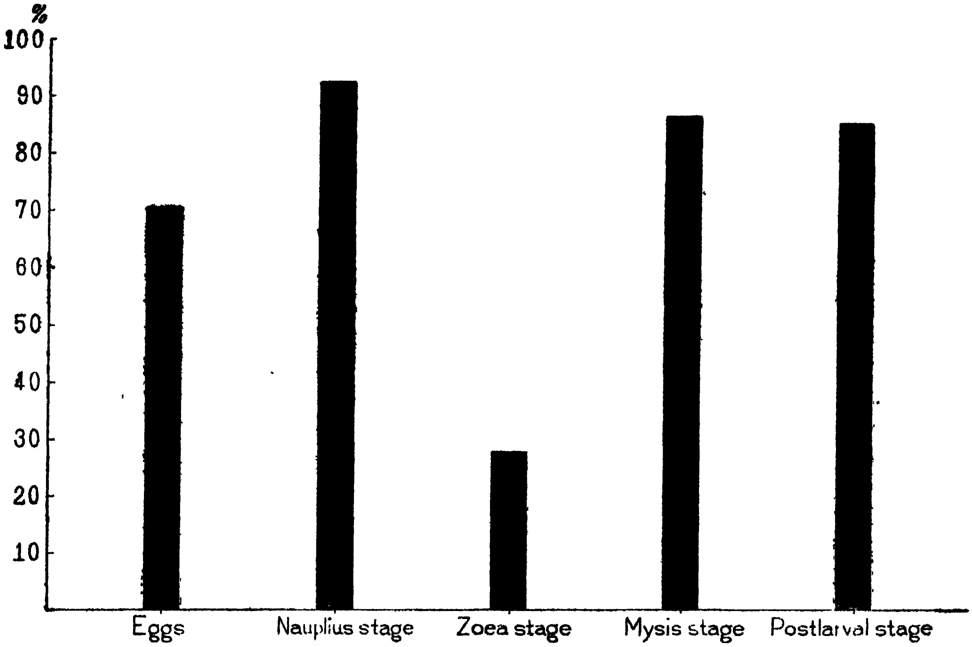

Fig. 37. Survival percentage of eggs and larvae.

Table 35

Relation between 1st–3rd post-larvae and low water-temperature

Salinity 30.5‰, 30 specimens examined.

Time elapsed		Water temp.	Remarks
hr.	min.	°C	
	0	24.0	All larvae swim actively in middle and lower layer.
	30	22.0	„
1	00	19.5	„
1	30	17.8	„
2	00	16.0	„
2	30	15.5	„
3	00	13.5	„
3	30	12.0	Some weaken, and movement of appendages somewhat sluggish.
4	00	10.0	Most sink to bottom and move appendages feebly.
4	30	9.0	Most asphyxial.
5	00	7.5	All asphixial.

The favorable water-temperature for various larval stages is shown in Table 32 and Fig. 38.

Table 36

Relation between 1st-3rd post-larvae and high water-temperature

Salinity, 30.5‰, 30 specimens examined.

Time elapsed hr.	min.	Water temp. °C	Remarks
	0	25.0	All larvae swim actively in middle layer and near bottom.
	30	28.0	"
1	00	30.5	"
1	30	31.5	"
2	00	32.1	"
2	30	33.5	"
3	30	34.0	"
4	00	35.1	Some become weak, but movement of appendages active
4	30	37.0	Most become weak and sink to bottom, some asphyxial.
5	00	38.2	Most asphixial.
5	30	39.3	All asphyxial.

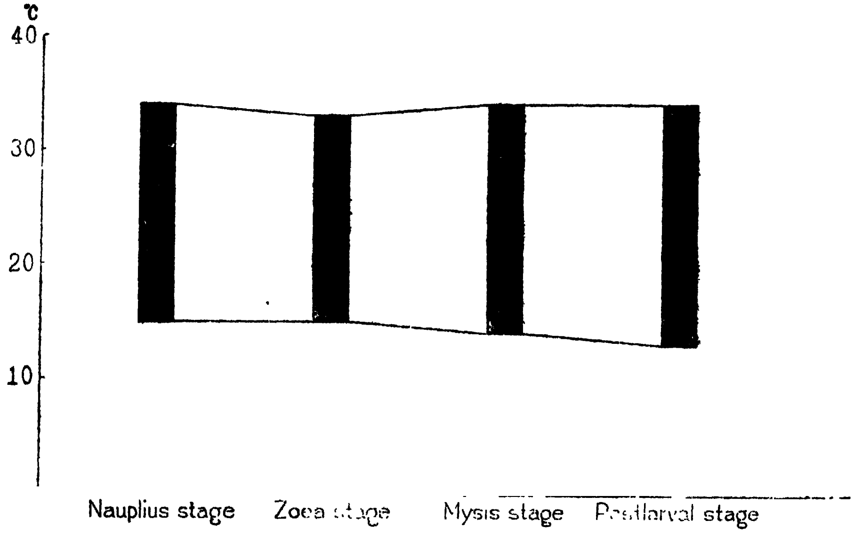

Fig. 38. Most suitable water-temperature for larvae.

V. Summary

1) In copulating act, the stopper is inserted into the thelycum, which is not the seminal receptacle, because there is for the deposition of the spermoto-

phore a special sack situated between the body wall and the thelycum. The sack is, therefore, the seminal receptacle.

2) Copulation takes place at night during the time from 0:00 a.m. to 3:00 a.m. between the male and the soft-female. Prior to copulation, the male pursues the female which undergoes ecdysis while being pursued. Soon after the ecdysis of the female the partners swim on their sides horizontally while the male embracing the soft-female. The male inserts the spermatophores with the stopper into the seminal receptacle of the female by means of petasma. Such habit as that the male protects the female until her shell becomes hard is not perceived in the present case. The male pursues the female no more after once copulated. The case is quite different from *Eusicyonia carinata* (Palombi 1939) whose male, not being satisfied with one copulation, repeats the act fifteen or twenty times. In the present prawn, the female once copulated casts away the spermatophores and stopper previously received from the male together with the body-shell in each ecdysis and receives afresh spermatophores and stopper from the male at the next copulation.

3) In the ovary the ova are naked not having the vitelline membrane, and in their ripening absorb follicle-cell contents into them and there is formed in the circumferential layer of the ovum a jelly-like substance which is ready to be extruded immediately after oviposition.

4) The spawning season lasts from the first decade of May to the end of September. In the early part of the season spawning occurs from about 8 p.m. to 12 p.m., while later in the season usually from about 0 a.m. to 4 a.m., spawning requiring only a short duration, 3 or 4 minutes. The prawn spawns while swimming in the shallow layer of the water and eggs diffuse soon after spawned. Should it spawns otherwise instead of while swimming, it does so while rapidly moving its abdominal appendages. If by chance the extruded eggs are not scattered in the water but accumulated in one spot, they become deformed and do not hatch. The same condition has been observed in *P. monoceros* and *P. affinis*. Writer's observation of the spawning act differs from that of Heldt in *P. trisulcatus*.

6) The eggs immediately after oviposition are irregular in shape and the jelly-like substance in the egg soon shoots out in radiating fashion. Thus, owing to the extrusion of jelly-like substance out of the ovum, the volume of the ovum decreases by 50%. Extruded jelly-like substance soon makes the egg-jelly all around the ovum after being soaked in the water.

7) The melting of the germinal vesicle of the ovum occurs just prior to the spawning. During the spawning act sperm deposited in the seminal receptacles are extruded through the tiny apertures situated at the bases of fourth pereiopods.

8) When a number of spermatozoa come and attach themselves to the surface of the ovum, same number of entrance cones appear, and when one spermatozoon enters into the cone and the ovum, the others remain only adhering to the surface of the cones, which eventually disappear afterwards.

9) The first polar body appears at almost the same instant when the

spermatozoon enters the ovum. The first polar body may or may not segment into two.

10) The fertilization membrane begins to appear and elevates from the ovum-cytoplasm in from 6 to 7 minutes after the entrance of the spermatozoon. The cytoplasm does not separate from the fertilization membrane at the very spot where the first polar body was extruded; the connection is still retained by a protoplasmic thread. Thus, the connection between the first polar body and the ovum-cytoplasm is still kept by the protoplasmic thread after the fertilization membrane is made.

11) The second polar body appears at the very spot of the ovum whence the first appeared. Therefore, the first and the second polar bodies are connected by the protoplasmic thread, and the latter ascends towards the former as if the former pulls in the latter by the connecting thread through the perivitelline space. On this occasion again, the second polar body and the ovum-cytoplasm are connected by a protoplasmic thread, which finally breaks when the second polar body arrives at its destined place just under the first, the two bodies not being in the direct attachment owing to the presence of the fertilization membrane between them.

12) The cleavage of the egg is perfectly total and equal. The most characteristic point is found in the process of the second cleavage. The two daughter-cells raised by the first segmentation rotate, while segmenting into four, in opposite direction to each other to such an extent that the axes of the left and the right side make usually from 45° to 60°, sometimes as much as 90°.

13) In the embryo the anlage of the second appendage appears first, that of the third next and that of the first in the end. The nauplius breaks the egg-shell and hatches out from 13 to 14 hours after the spawning in the water-temperature of from 27° to 29°C.

14) There are six moultings in the nauplius stage, three in the zoea and again three in the mysis, and the larva passes into the post-larva. Allied prawns, such as *P. monoceros* and *P. affinis*, similarly pass through the same number of larval substages.

15) The post-larva begins to creep on the surface of the sand by gradually changing its habit from the planktonic to the benthosic, while moulting and growing, and after fifteen to twenty ecdyses its body together with all appendages attains the adult form. The gills develop from the first mysis and are completed in the eleventh post-larva.

16) The lowest salinity for the egg, nauplius and zoea to live in is about 27‰ and that for mysis and post-larva 23‰. The highest limit of salinity for egg and nauplius is about 35‰, for zoea not over 35‰, for mysis nearly 45‰ and for post-larva 47‰. The salinity of the habitat of the prawn in the nature varies from 27‰ to 32‰, usually being about 30‰.

17) The suitable temperature range is fairly wide for all stages; larvae thrive well in the water-temperature of from 15° to 33°C.

18) After the first zoea the larvae begin to feed and take whatever kinds

of food there are afforded to them, for example, copepods, water-fleas, diatoms and even the nauplius of its own kind. In the present study *Skeletonema costatum* artificially cultured was used as food for the rearing of the larvae in the zoea stage and it gave satisfactory result.

19) In the rearing experiment the hatch percentage of the egg showed over 70%, survival percentage in the nauplius over 90% and in the mysis and post-larva both above 80%, while in the zoea only about 28%, a poor result. Judging from the above result, it is not much difficult to obtain post-larvae of 13% from the spawns by rearing them artificially. It follows that we can raise 13,400–26,800 post-larvae from a single adult female from which 100,000–200,000 eggs are obtainable.

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EXPLANATION OF PLATES

Plate XVI

Thelycum and seminal receptacle before copulation.

Fig. A. Thelycum, ventral view.
Fig. B. Thelycum, ventral wall of it cut away, ventral view.
Fig. C. Seminal receptacle, dorsal view.

dw, dorsal wall of thelycum; *h*, hole to connect with seminal receptacle; *o*, opening from which eggs extrude; *Pr-3*, *Pr-4*, *Pr-5*, 3rd, 4th and 5th pereiopods; *sr*, seminal receptacle; *vw*, ventral wall of thelycum.

Plate XVII

Thelycum, stopper, seminal receptacle and spermatophore after copulation.

Fig. A. Ventral view.
Fig. B. Lateral view.
Fig. C. Dorsal view.

dw, dorsal wall; *Pr-3*, *Pr-4*, *Pr-5*, 3rd, 4th and 5th pereiopods; *st*, stopper; *sp*, spermatophore; *sr*, seminal receptacle; *vw*, ventral wall of thelycum.

Plate XVIII

Fig. 1. Concrete tanks in which late post-larvae are reared.
Fig. 2. Manner in which the male prawn follows the female prior to copulation. ×1/3.
Fig. 3. Attitude of the prawns in copulation. ×5/9.

Figs. 2-3. Photographs taken of the prawns removed from the tank after copulation and postured artificially as they are copulating.

Plate XIX

Fig. 1. Immature ovarian egg.
Fig. 2. A slightly developed ovarian egg.
Fig. 3. A greatly developed ovarian egg.

Figs. 1-3. Greatly enlarged.
fc, follicle-cell; *js*, jelly-like substance.

Fig. 4. Jelly-like substance in egg crushed on slide glass.
Fig. 5. A moulted shell, ventral view. ×1.
st, stopper.
Fig. 6. A moulted shell, dorsal view. ×1.
sp, spermatophore.

Plate XX

Figs. 1-6. An egg immediately after being spawned; jelly-like substance extruded from the egg becomes granules and disappears. ×80.
js, jelly-like substance; *gr*, granule; *1st pb*, 1st polar body.
Fig. 7. An egg before 1st cleavage. ×170.
2nd pb, 2nd polar body.

Plate XXI

Diagrammatic illustration of fertilization.

Fig. A. Before entrance cones appear.
Fig. B. After entrance cones appeared.

Plate XXII

Diagrammatic illustration of fertilization.

Fig. A. Before entrance cones appear.
Fig. B. Entrance cones begin to elevate.
Fig. C. Entrance cones reach maximum height and cytoplasm begins to elevate as entrance cones.
Fig. D. Cytoplasm attaches itself to head of a spermatozoon.
Fig. E. Entrance cones begin to retract.
Figs. F, G, H. The instant when one spermatozoon enters into egg and the other is agglutinated on the egg-surface.

Plate XXIII

Diagrammatic illustration of elevation of fertilization membrane and the appearance of the 2nd polar body.

Fig. A. The instant when the fertilization membrane begins to elevate.
Fig . B, C, D. Cytoplasm separates from fertilization membrane and becomes spherical, yet they are joined by the protoplasmic thread.
Fig. E. 2nd polar body appears on the cytoplasm.
Fig. F. 2nd polar body rises to 1st polar body.
Fig. G. 2nd polar body attaches itself to fertilization membrane.
Fig. H. Connecting thread cut away.

1st pb, 1st polar body; *2nd pb*, 2nd polar body; *pt*, protoplasmic thread.

Plate XXIV

Fig. 1. Part of egg-mass before 1st cleavage. ×40.
Fig. 2. Part of egg-mass, beginning of 1st cleavage. ×40.
Fig. 3. Part of egg-mass, end of 1st cleavage. ×40.
Fig. 4. An egg, beginning of 2nd cleavage, apical view. ×175.
Figs. 5–6. Process of 2nd cleavage, lateral view. ×170.
Fig. 7. Part of egg-mass, end of 2nd cleavage. ×40.

Plate XXV

Fig. 1. 8-cell stage. ×170.
Fig. 2. 16-cell stage. ×170.
Fig. 3. 32-cell stage. ×170.
Fig. 4. 64-cell stage. ×170.
Fig. 5. 128-cell stage. ×170.
Fig. 6. 256-cell stage. ×170.

Plate XXVI

Fig. 1. Embryo, 2 hours after spawning, viewed from vegetative pole. ×170.
ic, invagination cavity.
Fig. 2. Embryo, 4 hours after spawning, ventral view. ×170.
Fig. 3. Embryo, 4 hours after spawning, ventral view. ×170.
2nd ant, 2nd antenna.
Fig. 4. Embryo, 4.5 hours after spawning, ventral view. ×170.
Fig. 5. Embryo, 5 hours after spawning, ventral view. ×170.
Fig. 6. Embryo, 6 hours after spawning, ventral view. ×170.

1st ant, 1st antenna; *m*, mandible.

Plate XXVII

Diagrammatic illustration of embryonal development; mainly the three appendages.

Fig. A. Dorsal view.
Figs. B–I. Lateral view.

1st ant, 1st antenna; *2nd ant*, 2nd antenna; *lb*, labrum; *m*, mandible.

Plate XXVIII

Figs. 1-2. Nauplius in egg-shell, immediately before hatching, 14 hours after spawning, ventral view. ×170.

Figs. 3-5. The instant when the nauplius in egg-shell hatches out, ventral view. Notice the cast embryonic membrane in Fig. 5. Figs. 3 4. ×170. Fig. 5. ×100.

Plate XXIX

Nauplius stage, lateral view. Roman numerals show number of substages.

Plate XXX

1st zoea, ventral view.

Plate XXXI

1st zoea
Fig. A. Early 1st zoea, dorsal view.
Fig. B. Later 1st zoea, dorsal view.
Fig. C. Mandible.
Fig. D. 1st maxilla.
Fig. E. 2nd maxilla.
Fig. F. 1st maxillipede.
Fig. G. 2nd maxillipede

Plate XXXII

Carapace, rostrum and abdomen in mysis stage, lateral view. Roman numerals show number of substages.

Plate XXXIII

Pereiopod in mysis stage. Roman numerals show number of substages and Arabic numerals the pereiopods.
ab, arthrobranchia.

Plate XXXIV

Carapace and rostrum in post-larval stage. Roman numerals show number of sub stages.

Plate XXXV

Same as Plate XXXIV.

Plate XXXVI

Telson and uropod in post-larval stage, dorsal view. Roman numerals show number of substages.

Plate XXXVII

1st antenna in post-larval stage. Roman numerals show number of substages.

Plate XXXVIII

2nd antenna in post-larval stage. Roman numerals show number of substages.

Plate XXXIX

Mandible in post-larval stage. Roman numerals show number of substages.

Plate XL

1st maxilla in post-larval stage. Roman numerals show number of substages.

Plate XLI

2nd maxilla in post-larval stage. Roman numerals show number of substages.

Plate XLII

1st maxillipede in post-larval stage. Roman numerals show number of substages
mb, mastigobranchia.

Plate XLIII

2nd maxillipede in post-larval stage. Roman numerals show number of substages.
ab, arthrobranchia; *ex*, secondary exopodite; *mb*, mastigobranchia;
pb, podobranchia.

Plate XLIV

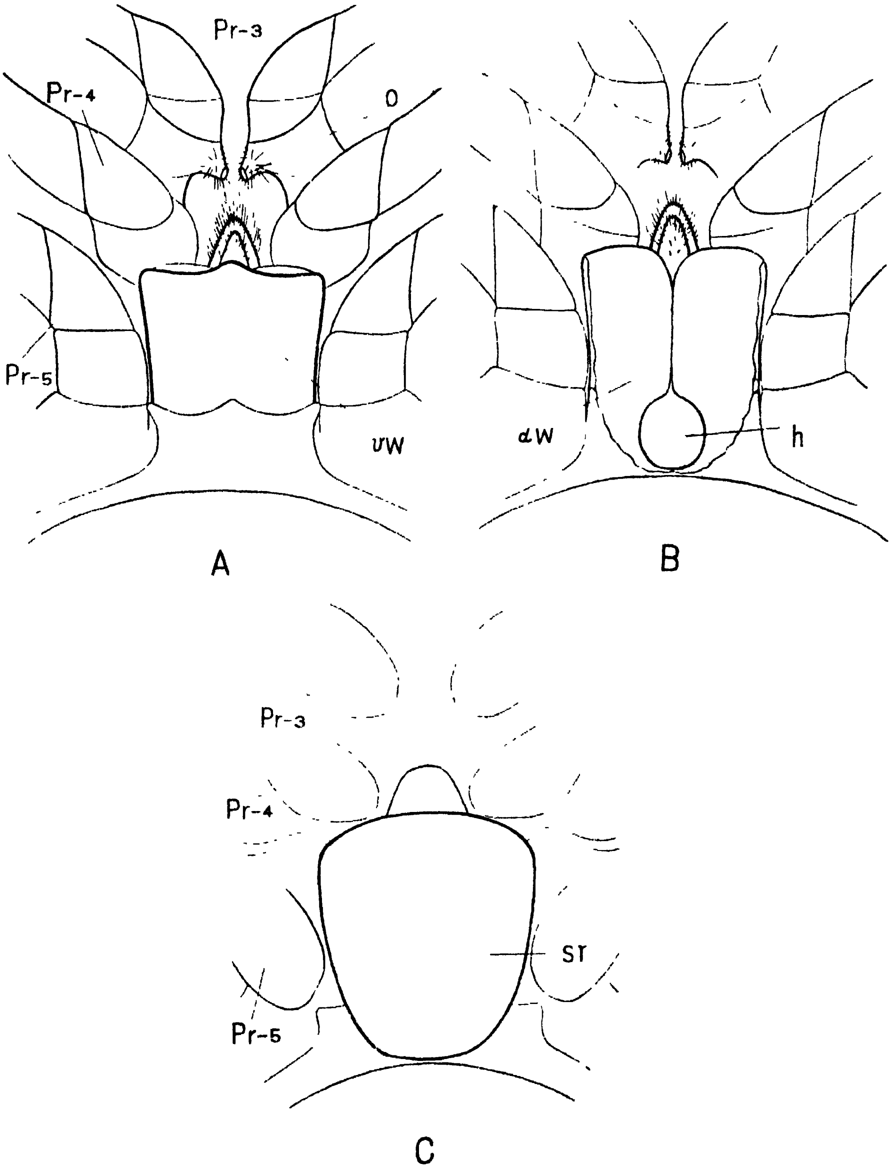
3rd maxillipede in post-larval stage. Roman numerals show number of substages.
ab, arthrobranchia; *ex*, secondary exopodite; *mb*, mastigobranchia;
plb, pleurobranchia.

Plate XLV

Pereiopod in post-larval stage. Roman numerals show number of substages and Arabic numerals pereiopods.
ab, arthrobranchia; *ex*, secondary exopodite; *mb*, mastigobranchia,
plb, pleurobranchia.

Plate XLVI

Same as Plate XLV.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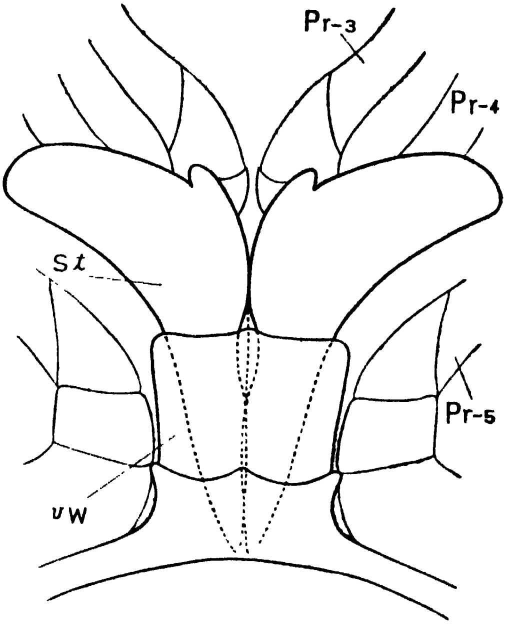

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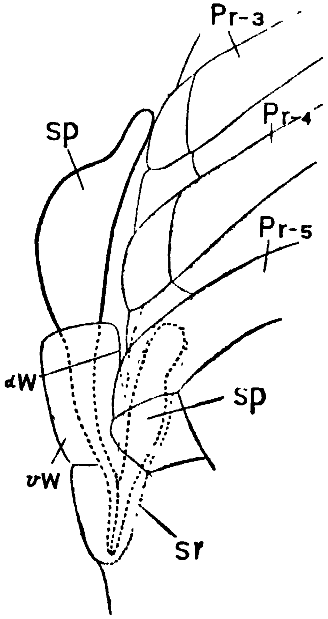

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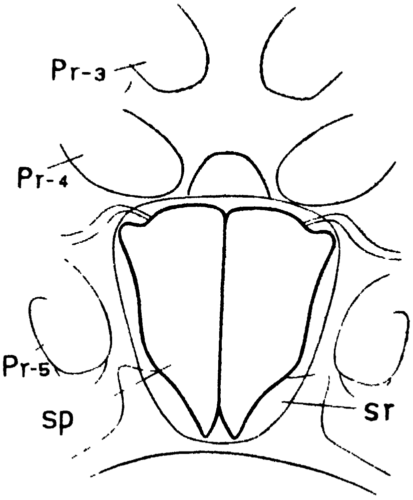

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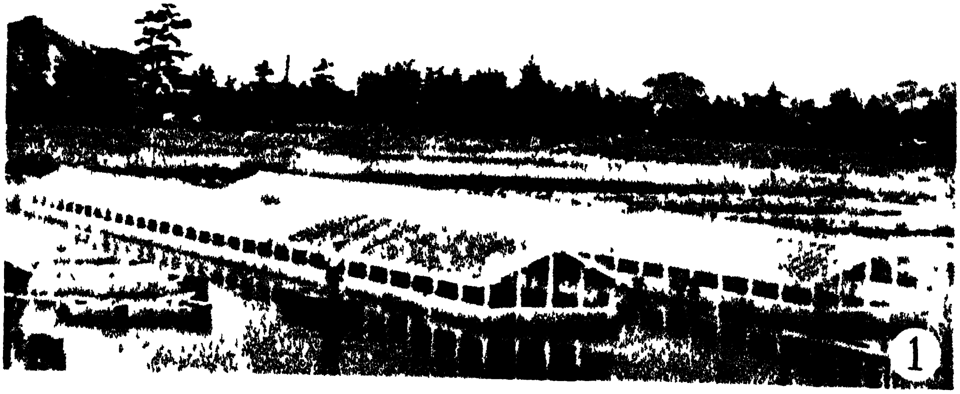

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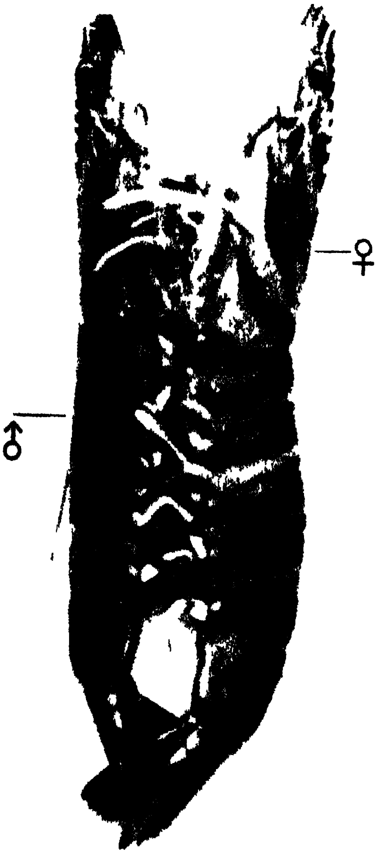

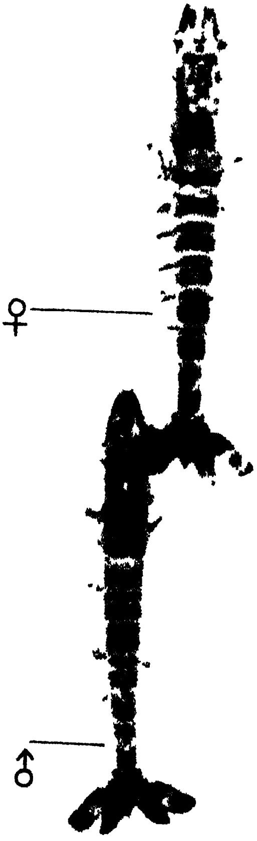

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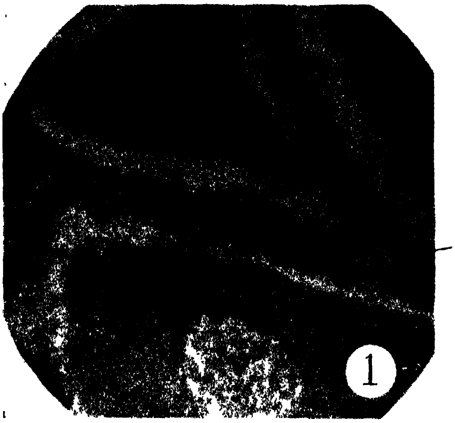
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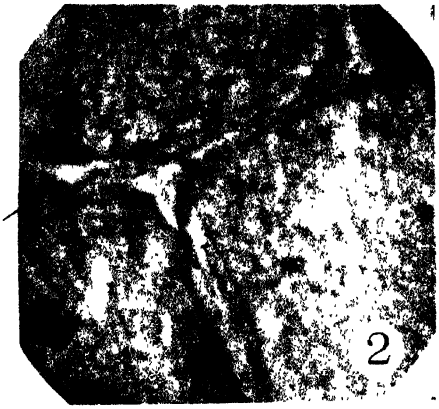
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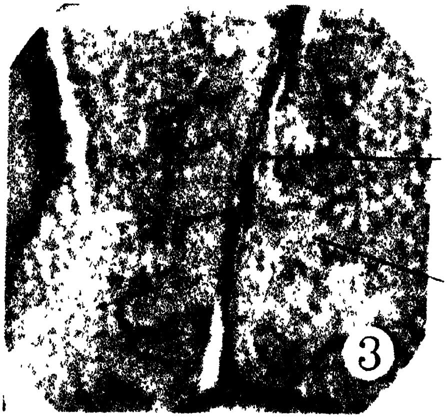
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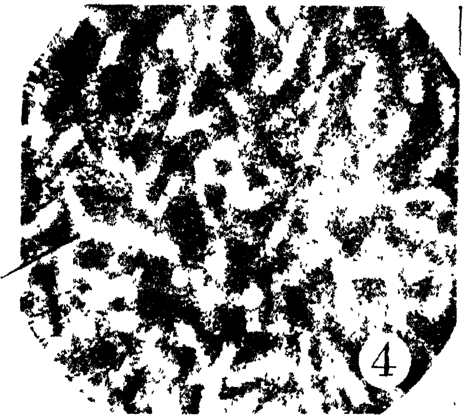
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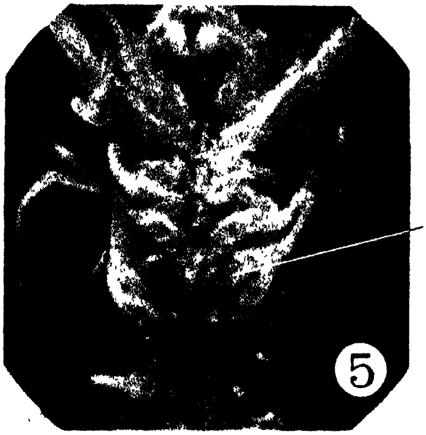
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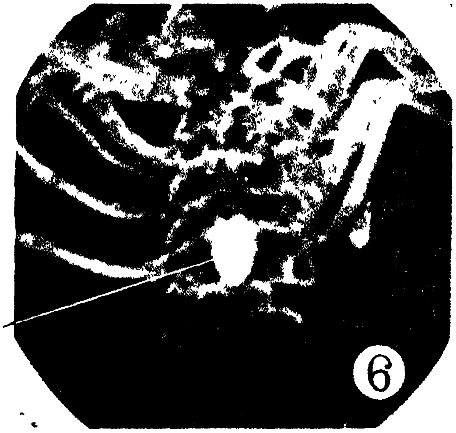
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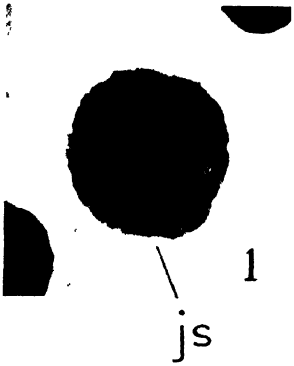

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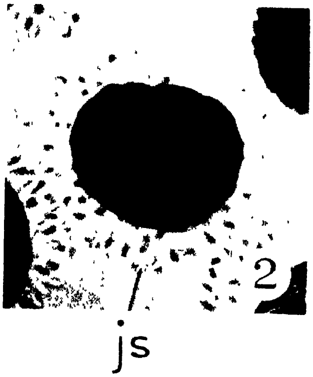

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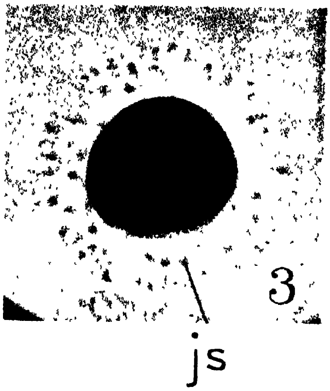

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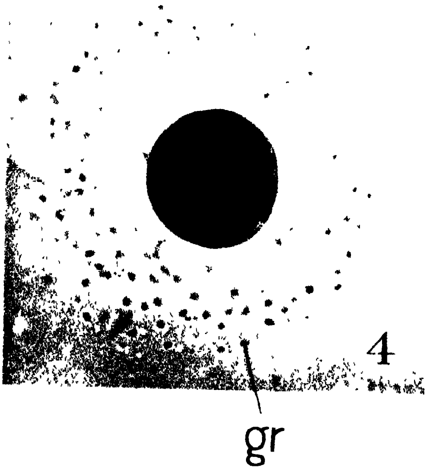

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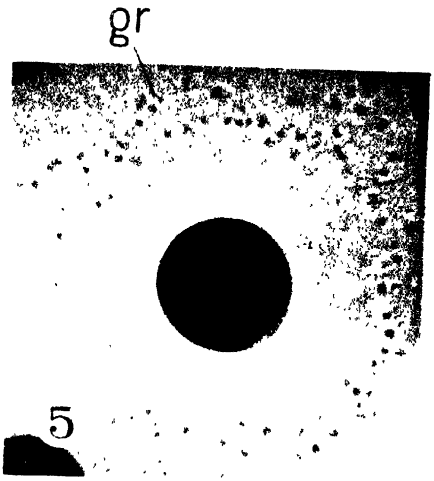

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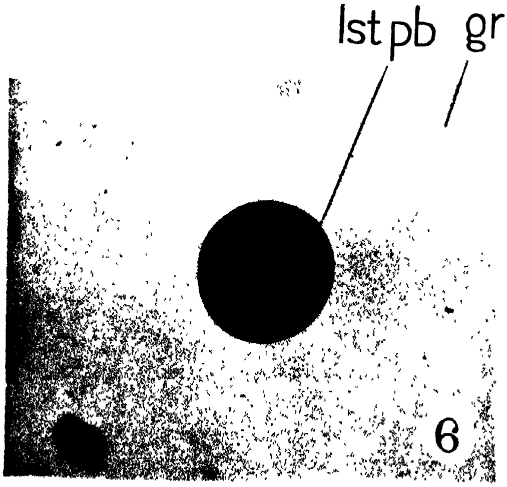

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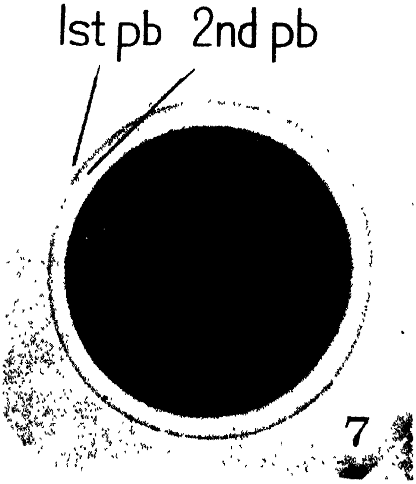

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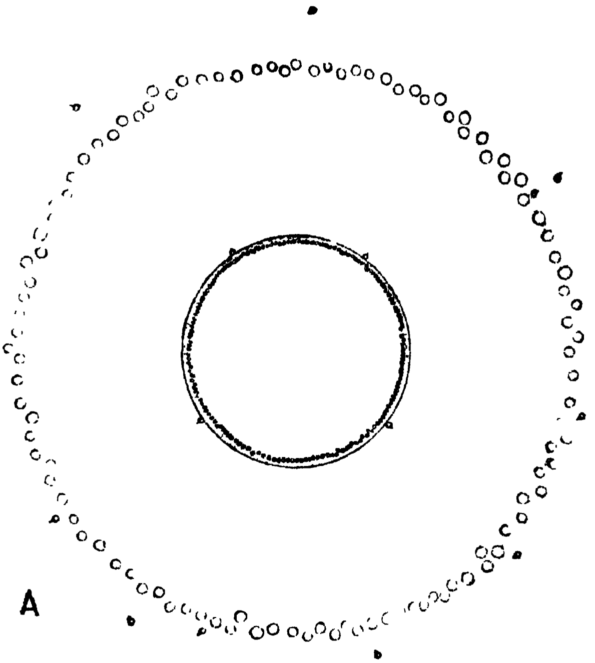

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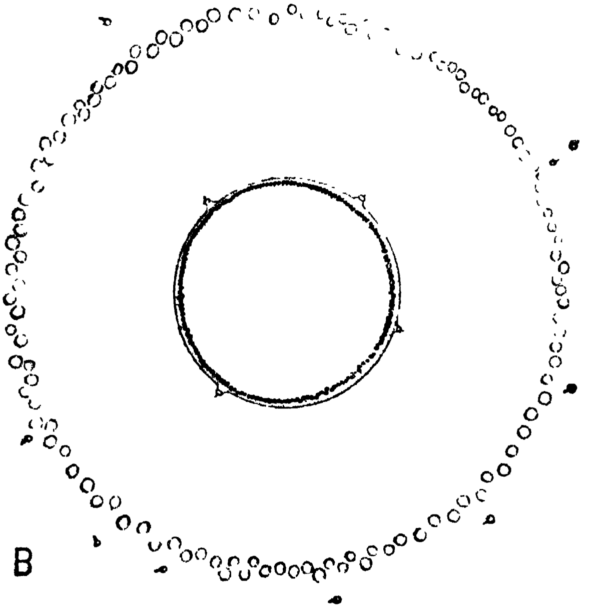

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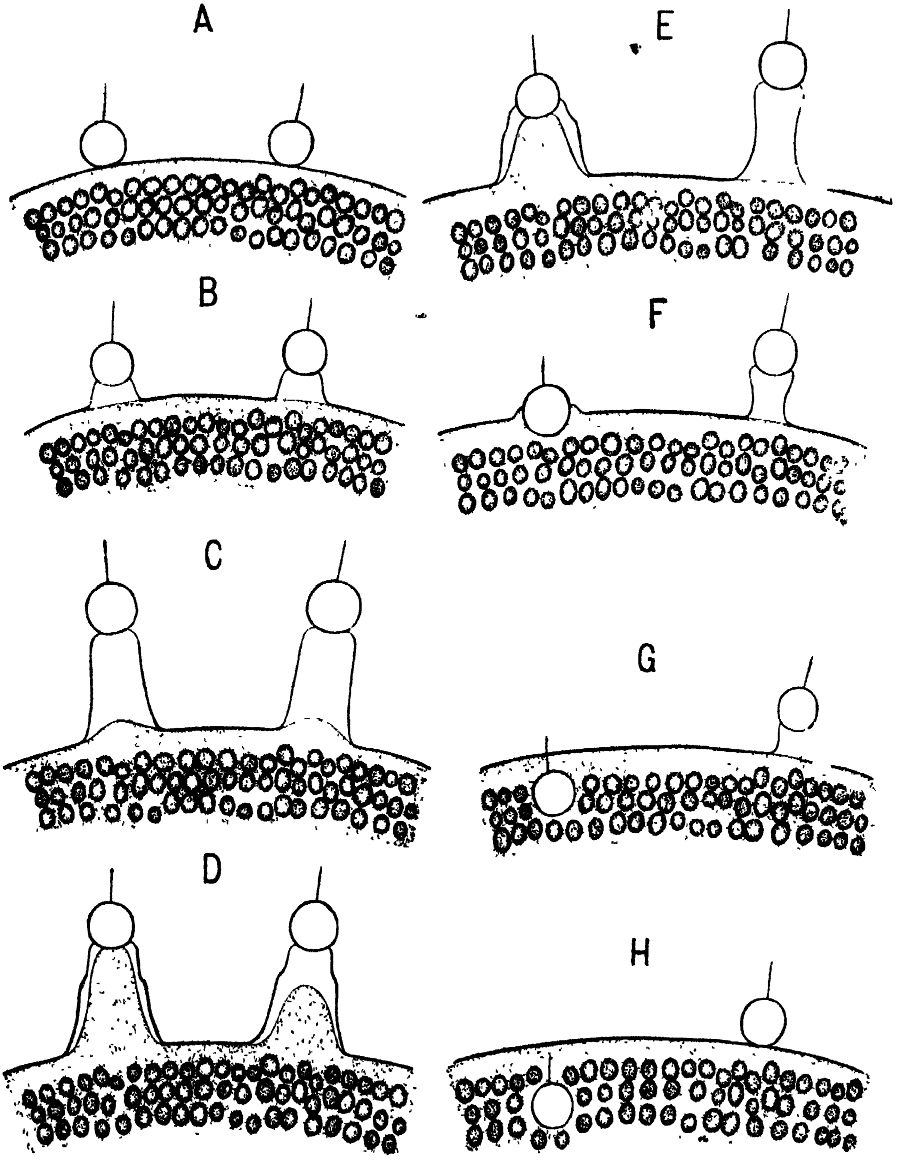
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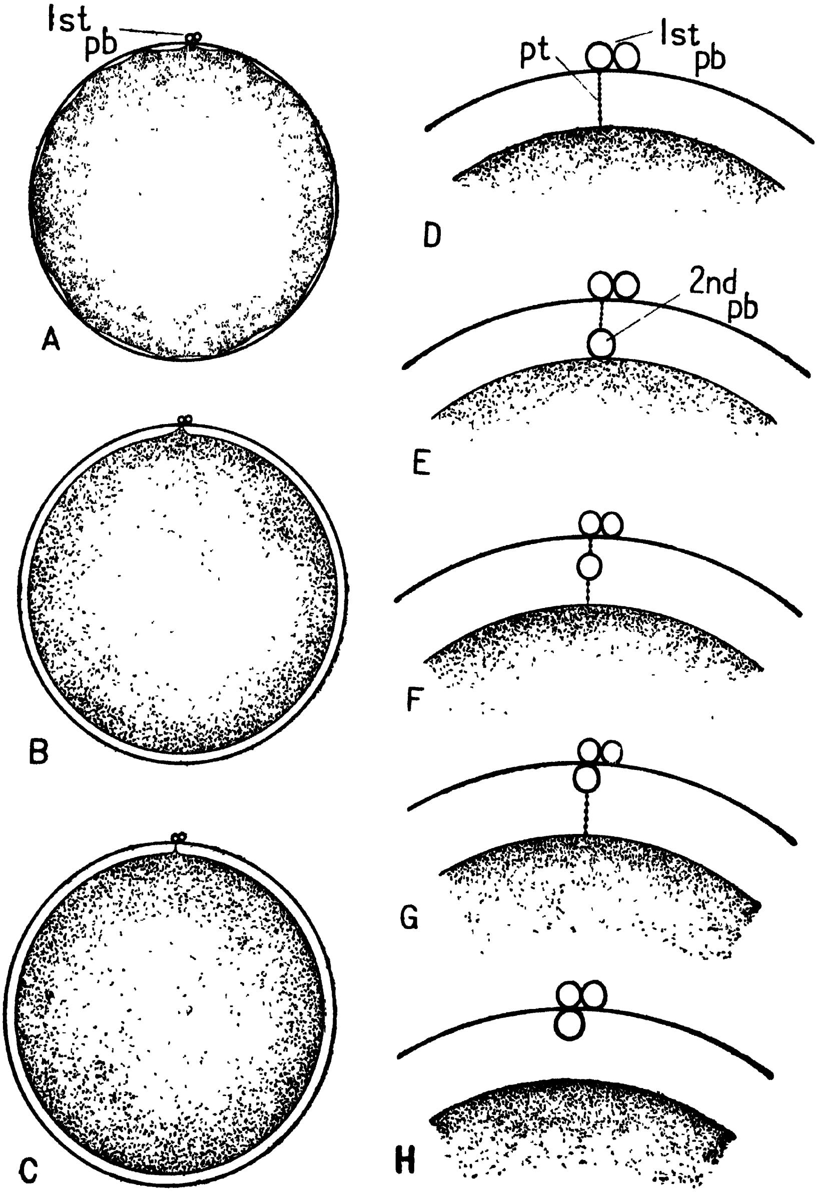
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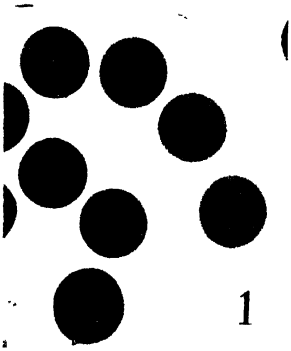
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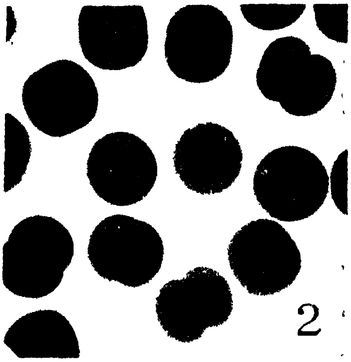
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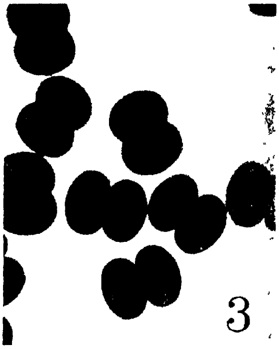
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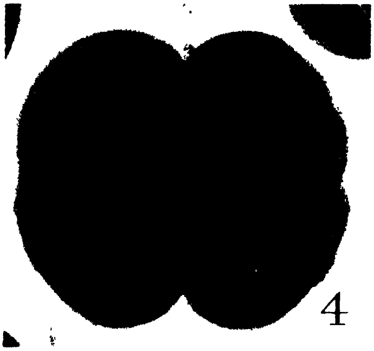
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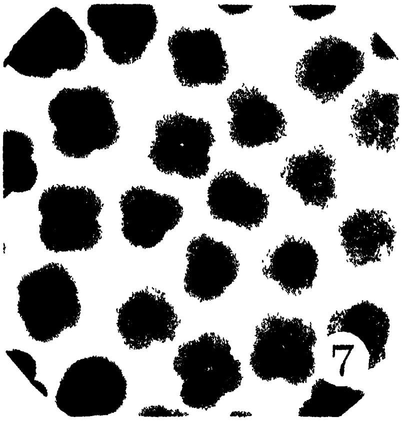
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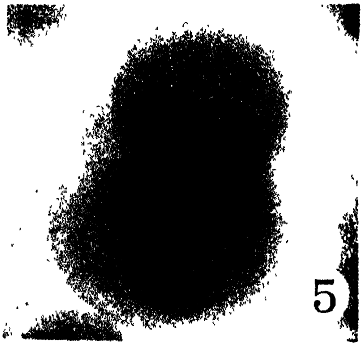
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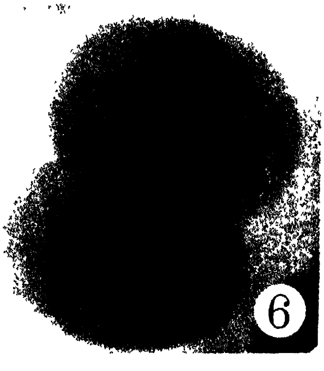
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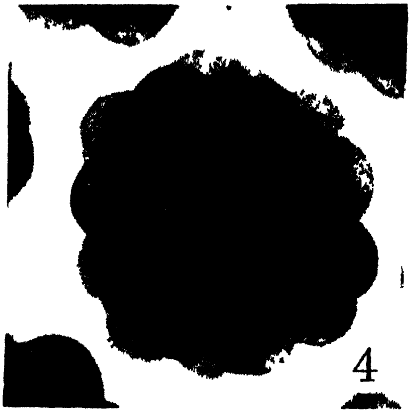

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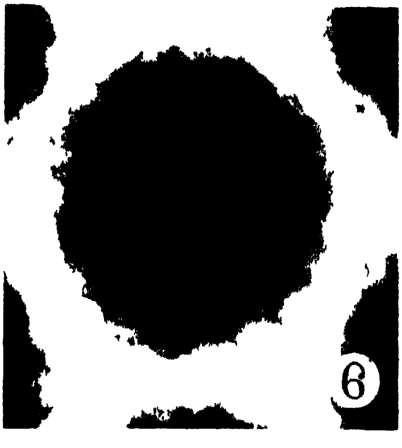

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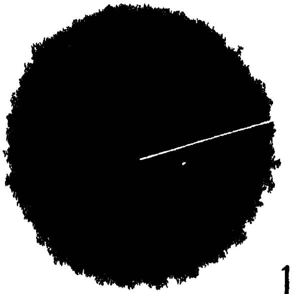

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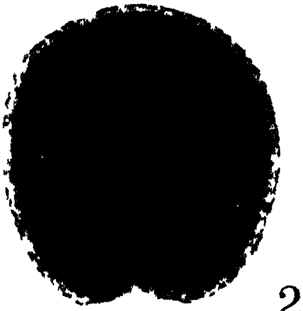

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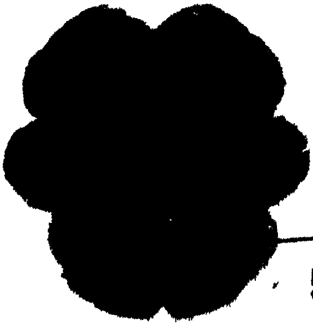

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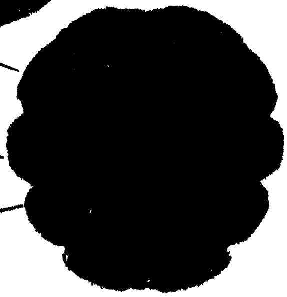

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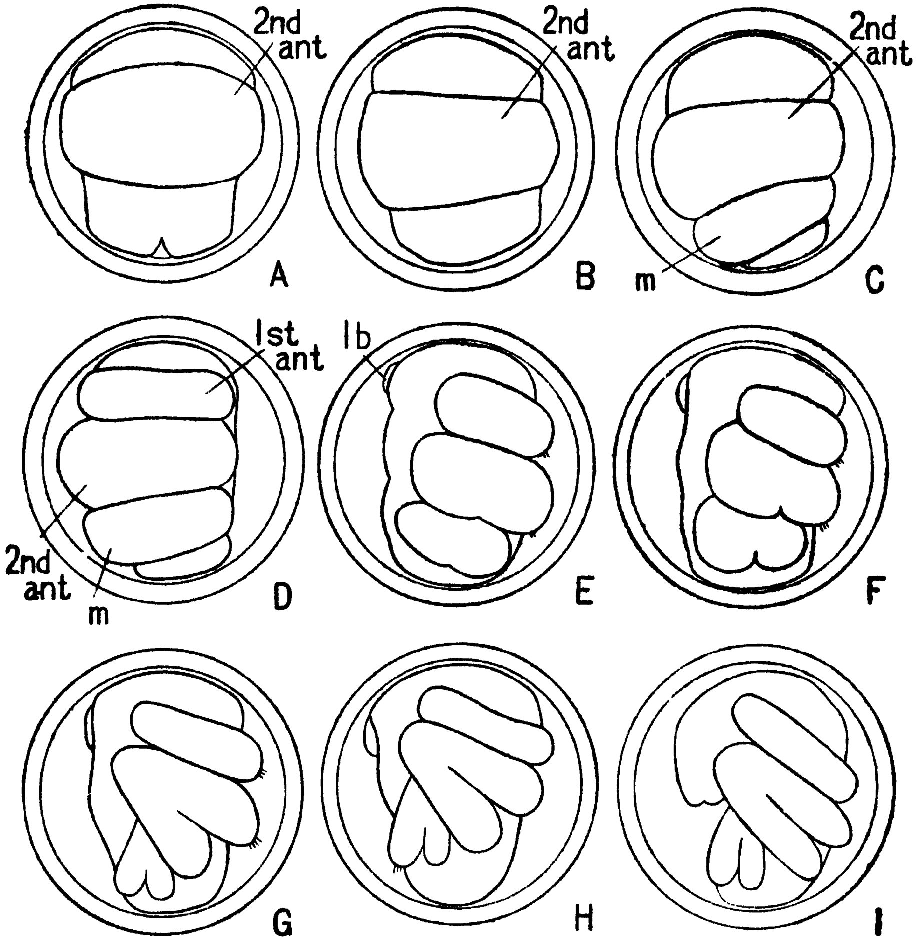
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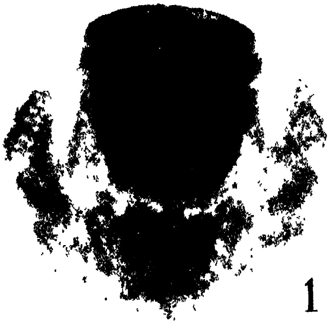

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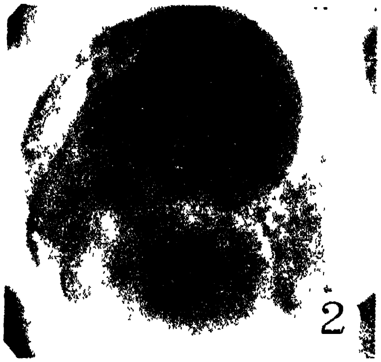

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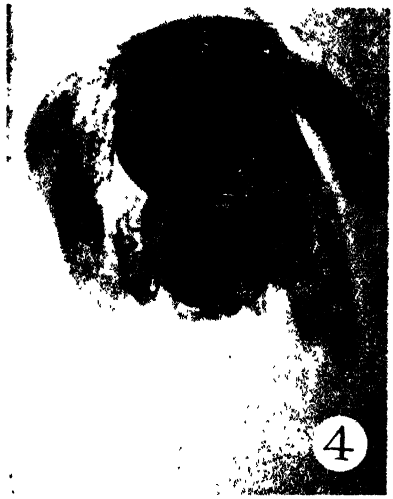

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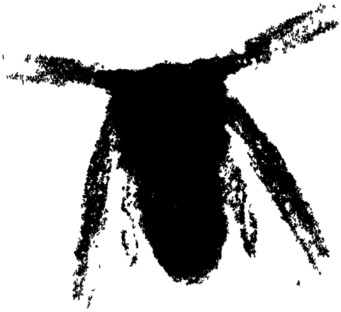

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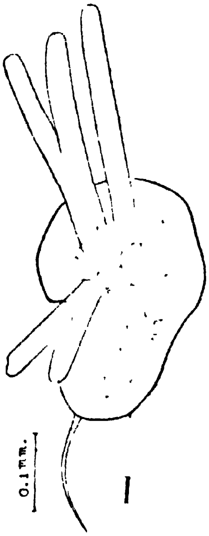

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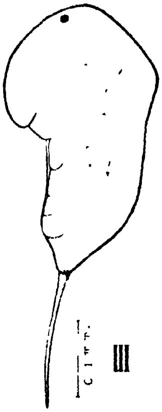

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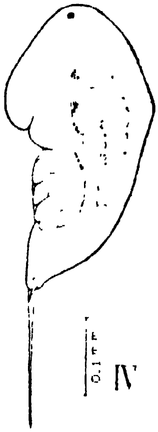

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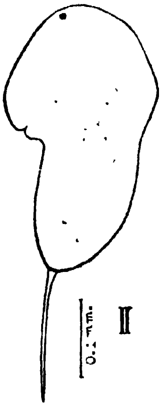

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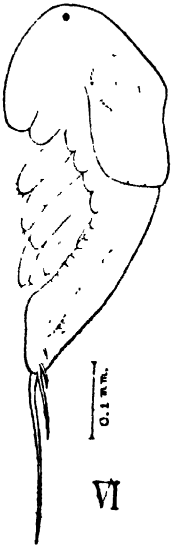

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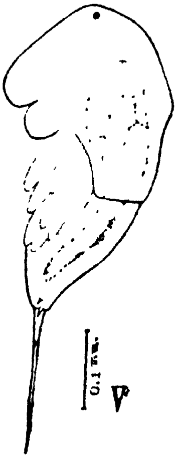

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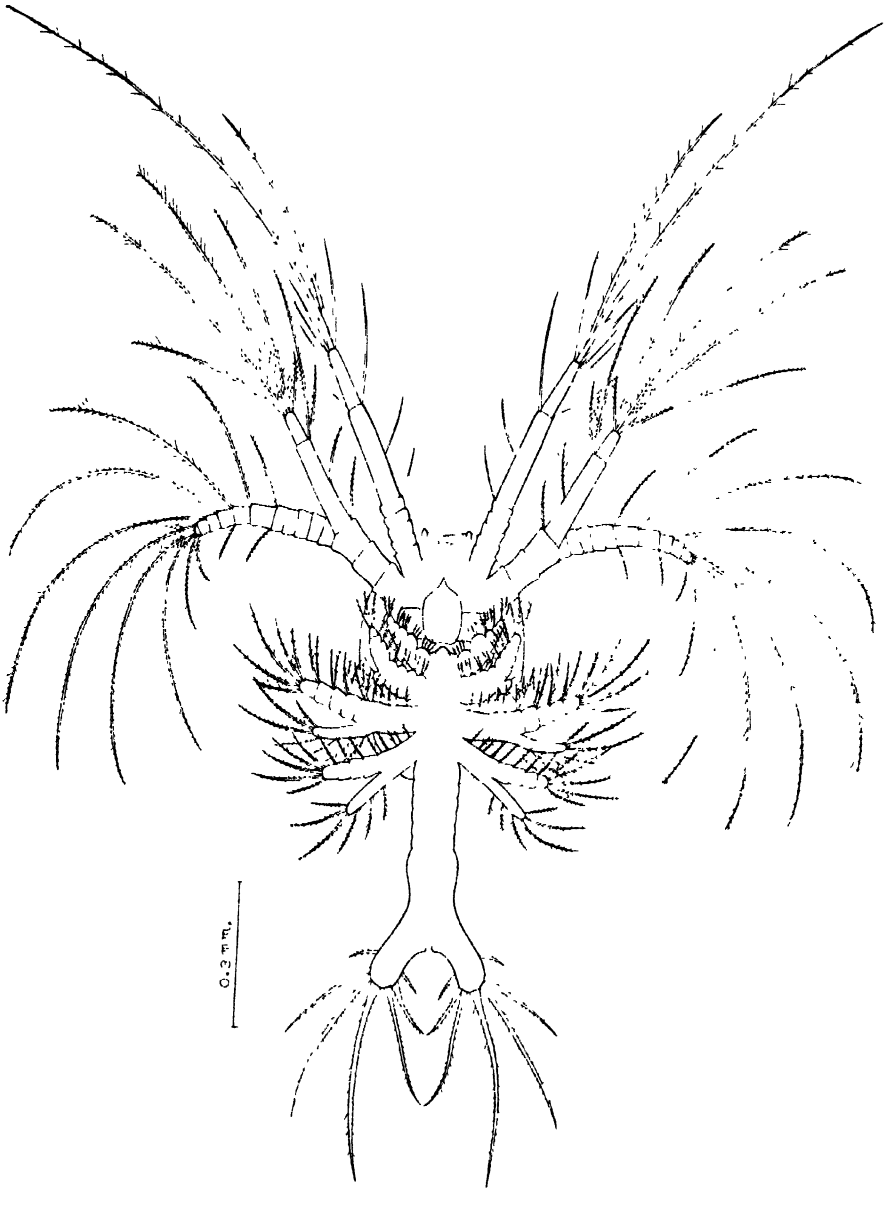
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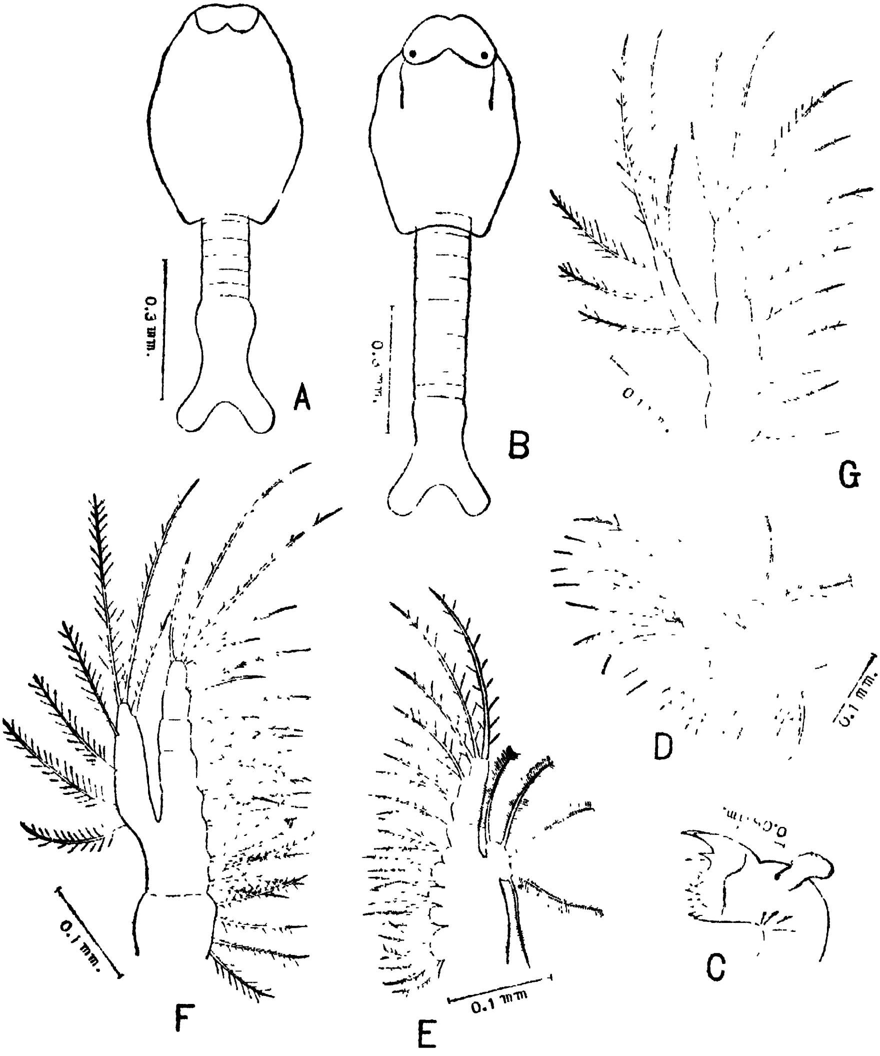
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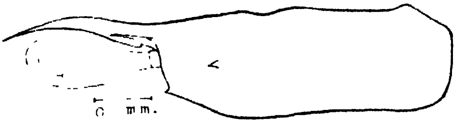

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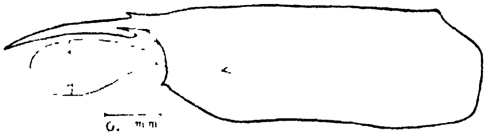

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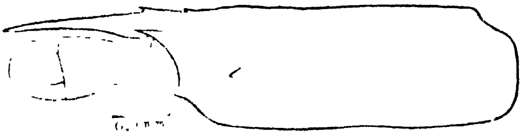

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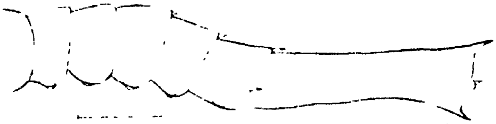

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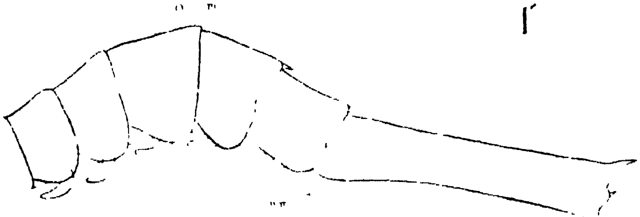

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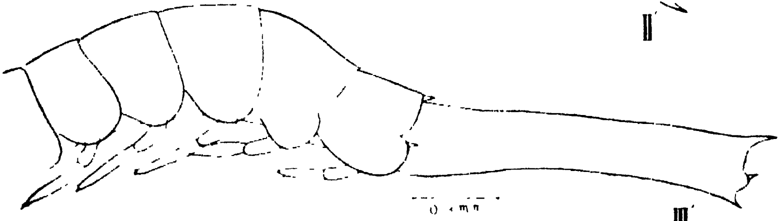

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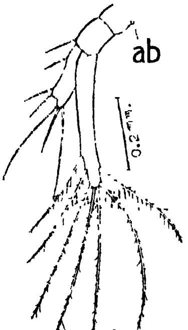

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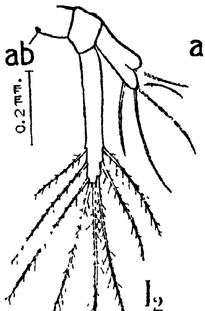

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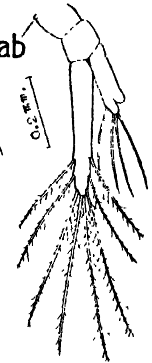

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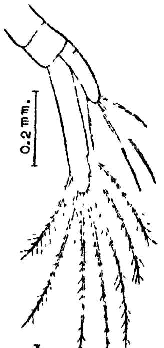

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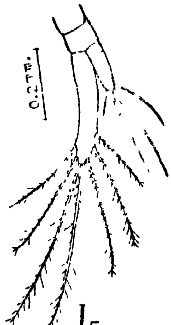

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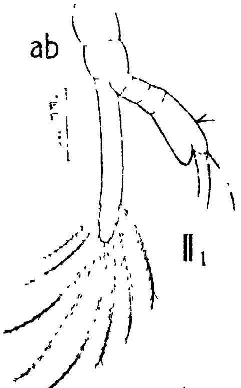

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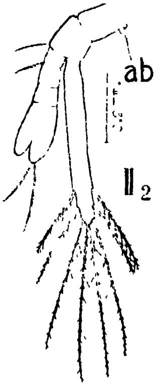

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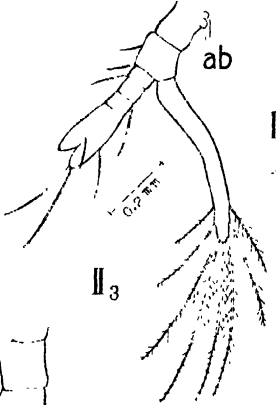

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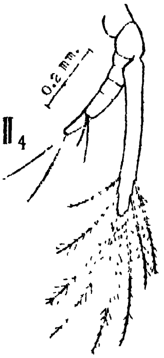

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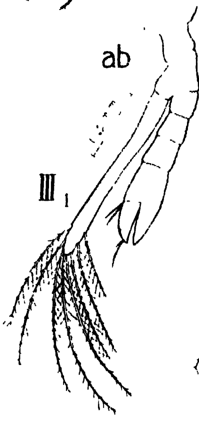

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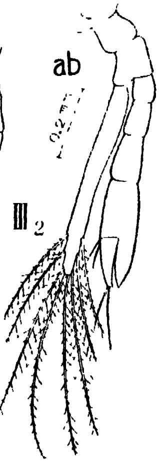

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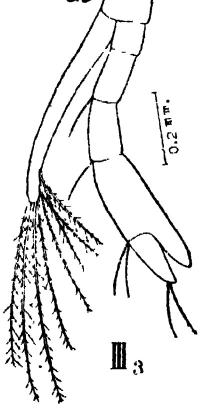

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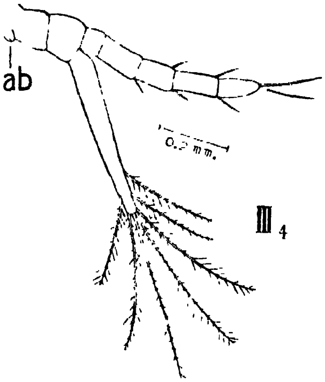

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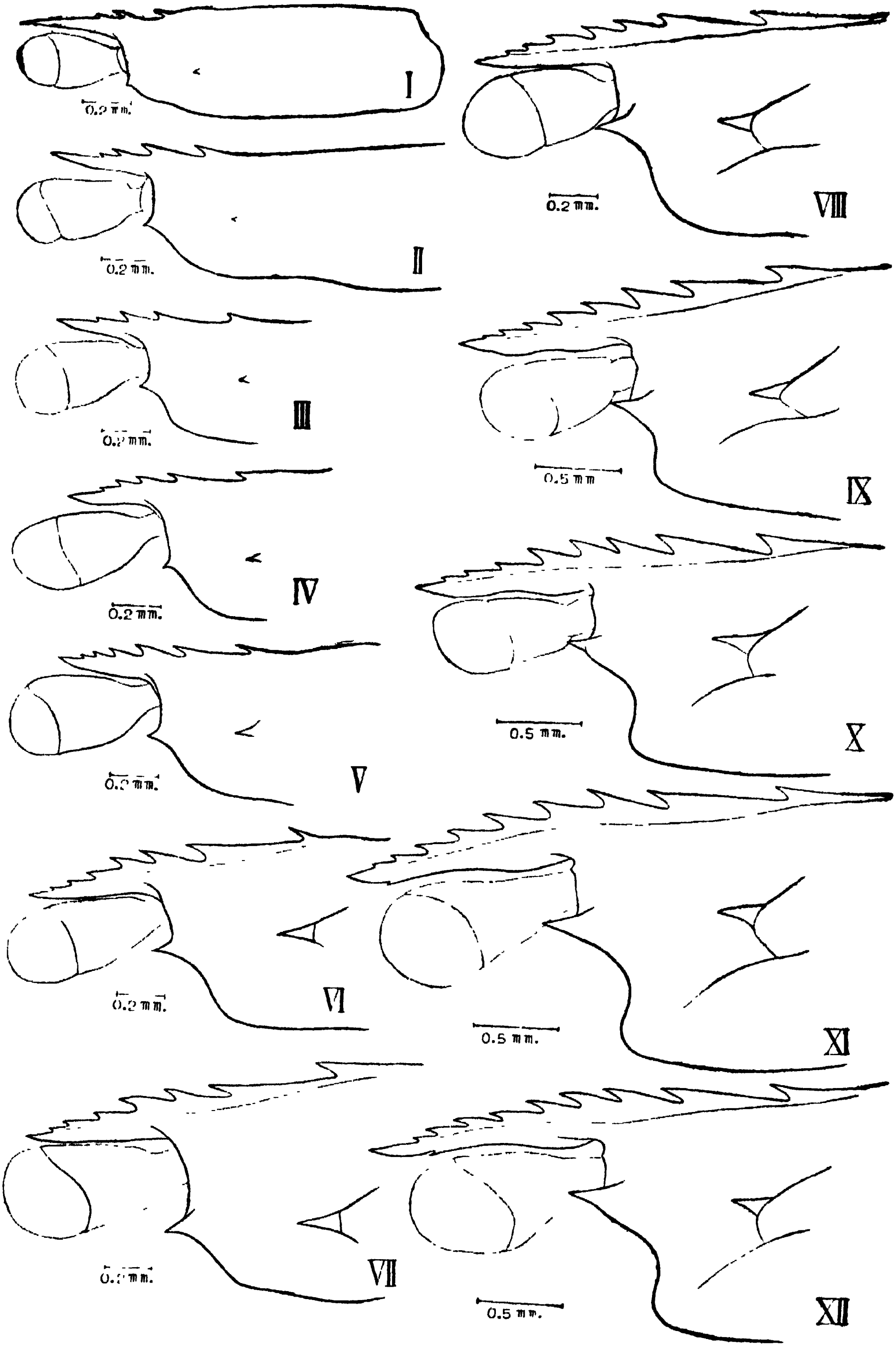
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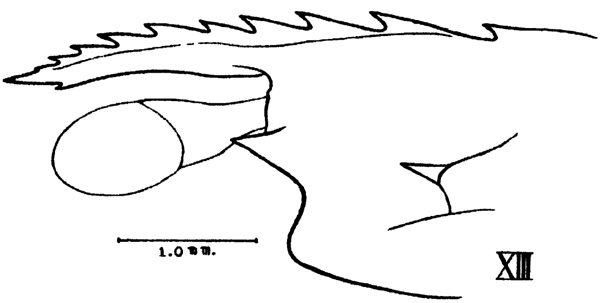

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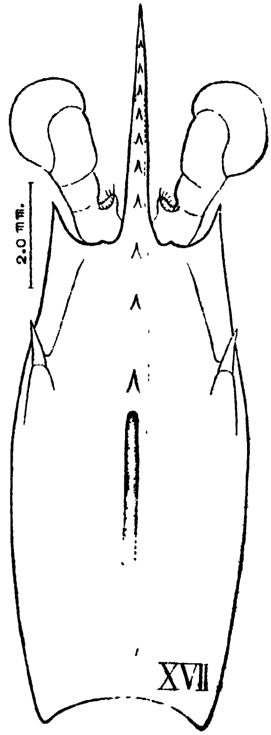

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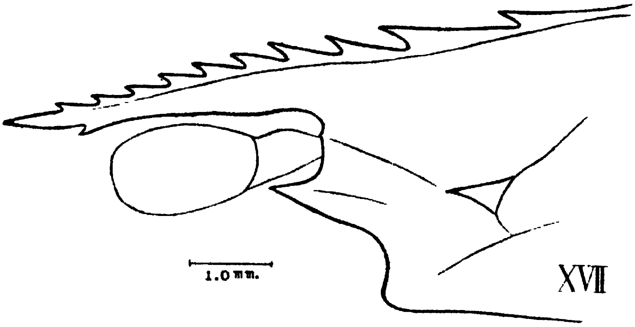

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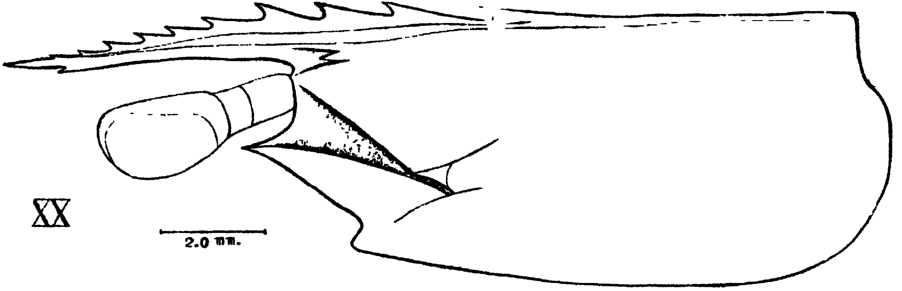

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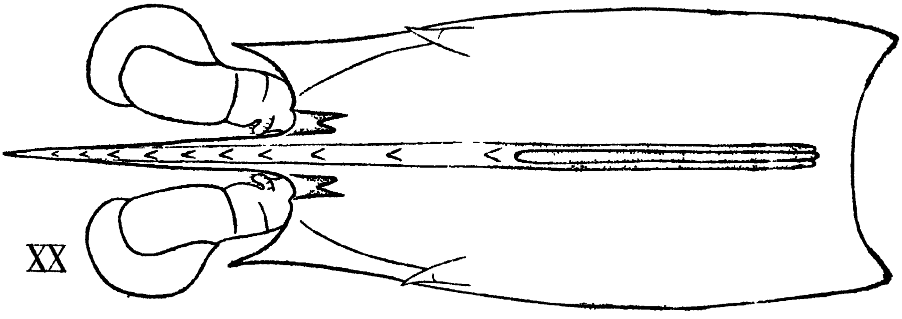

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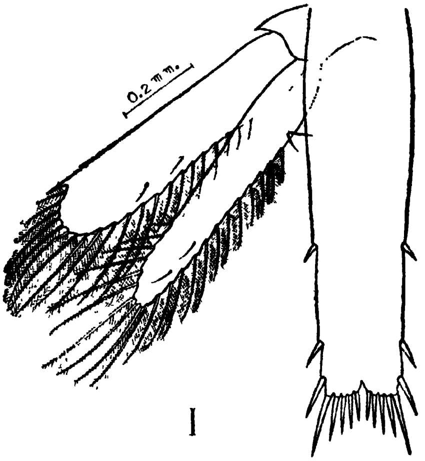

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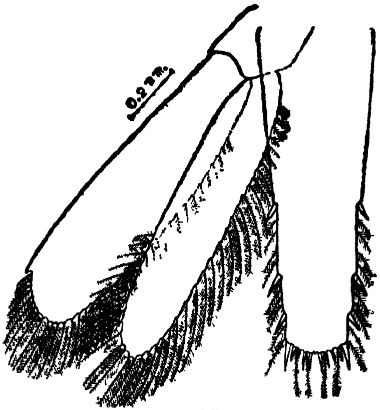

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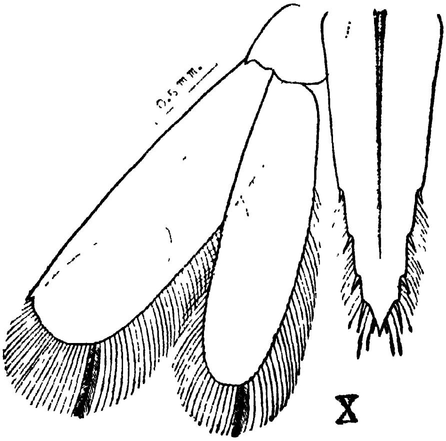

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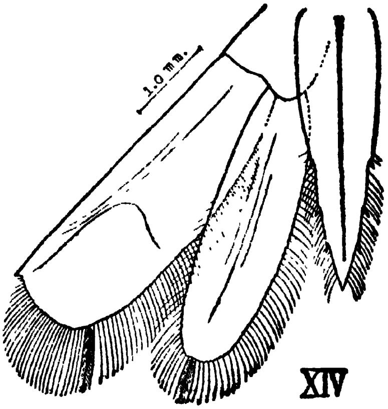

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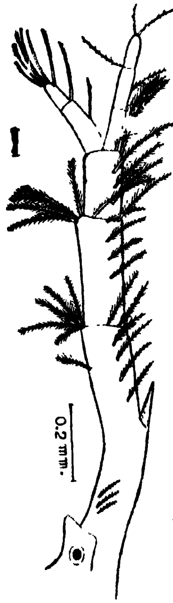
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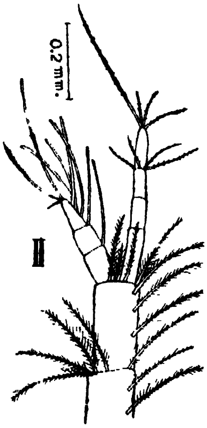
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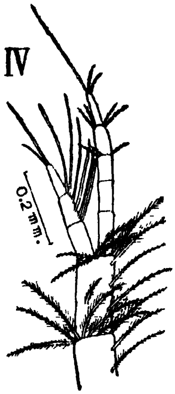
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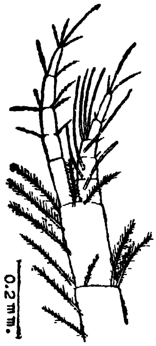
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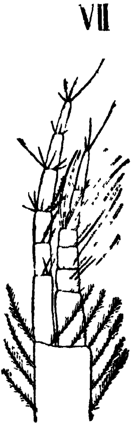
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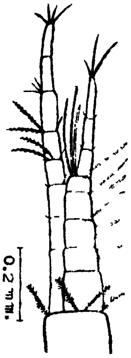
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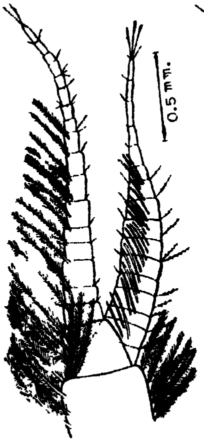
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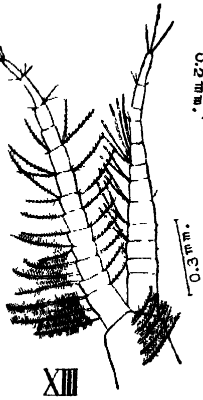
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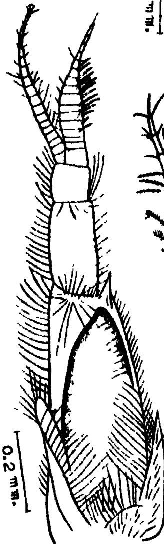
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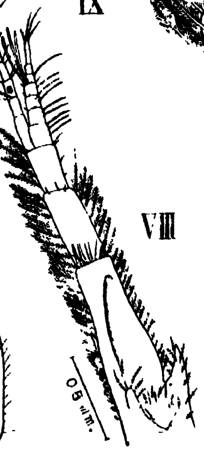
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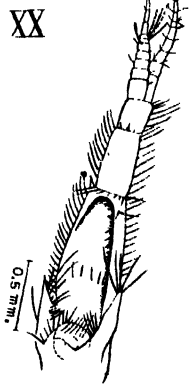
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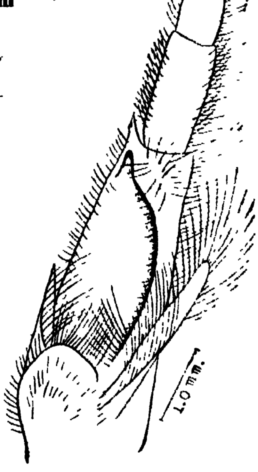
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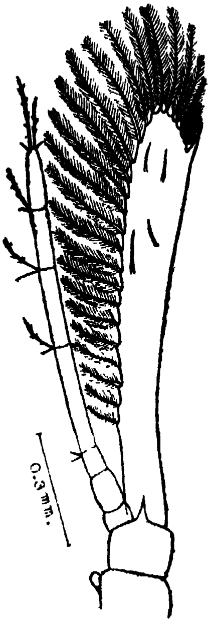

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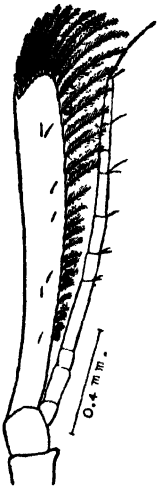

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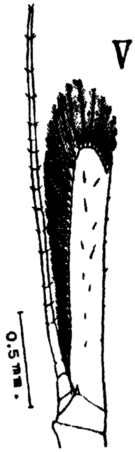

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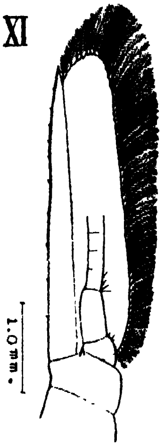

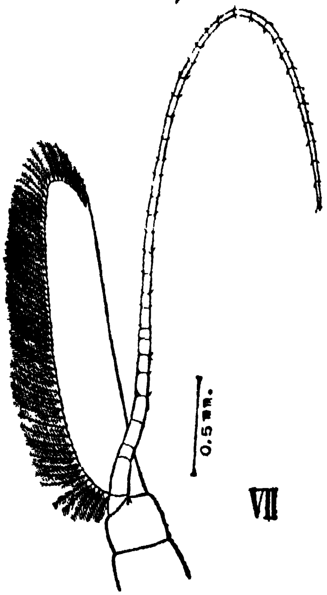

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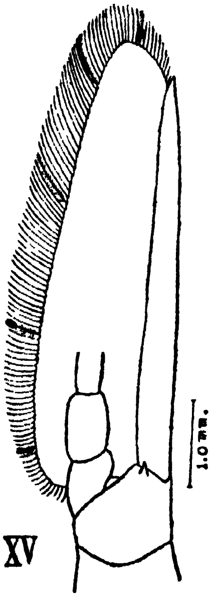

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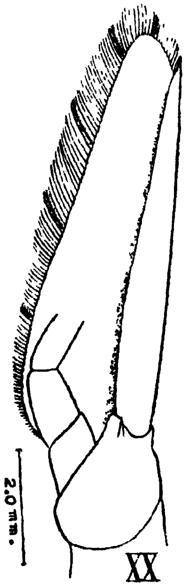

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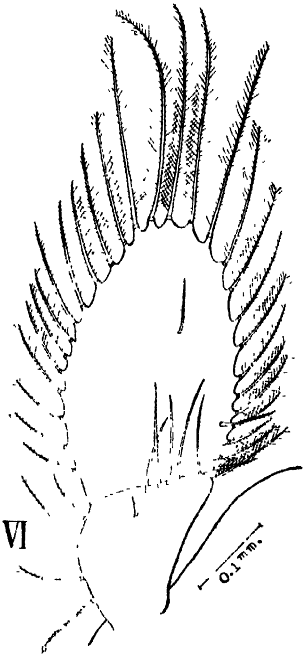
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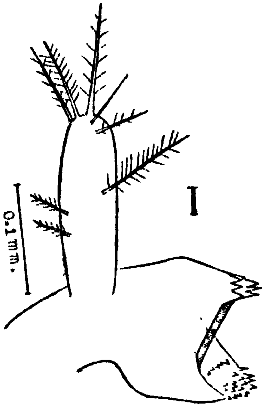
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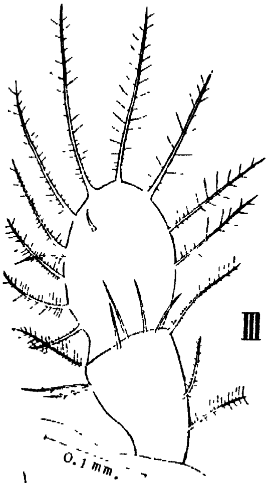
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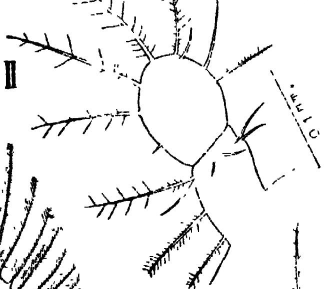
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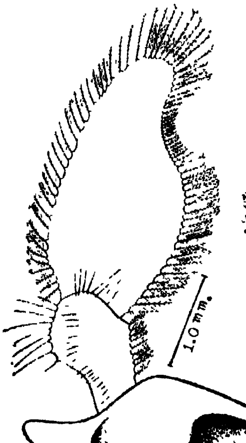
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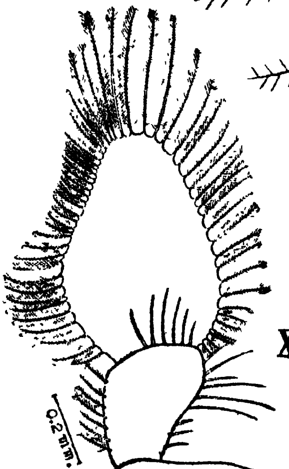
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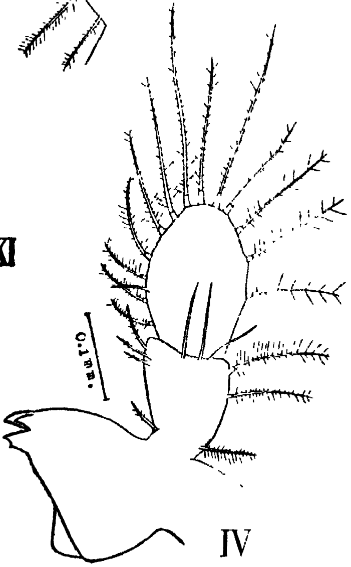
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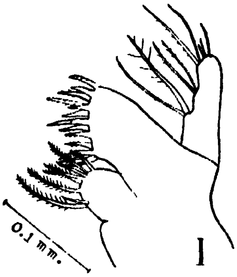
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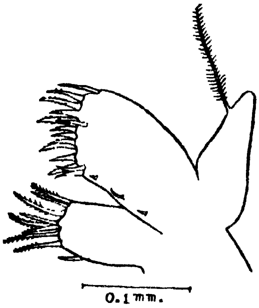
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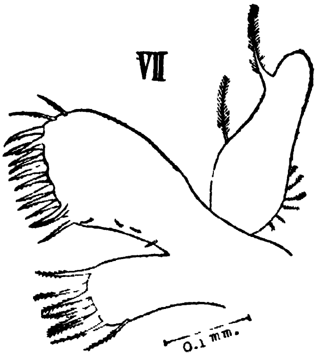
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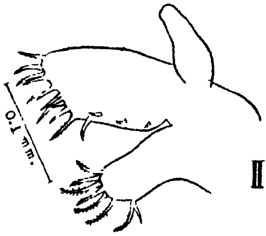
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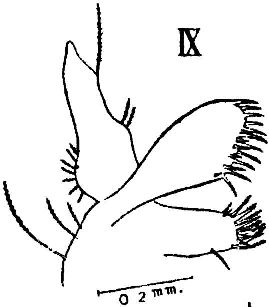
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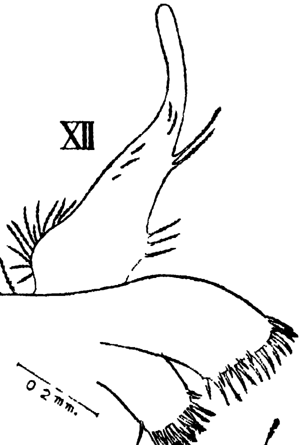
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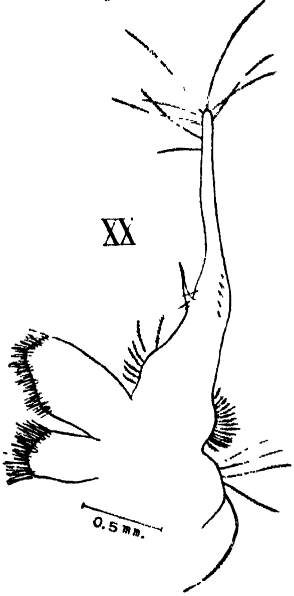
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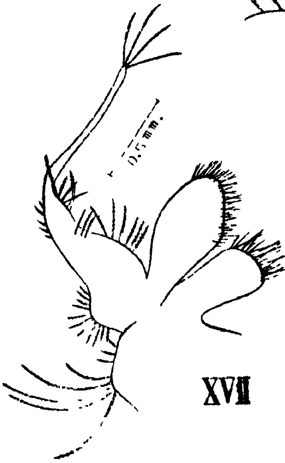
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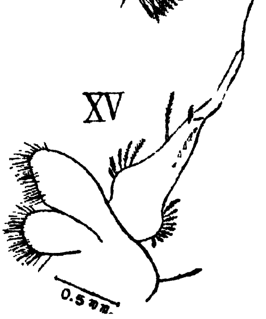
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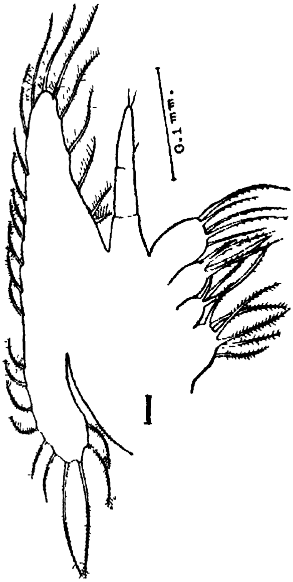
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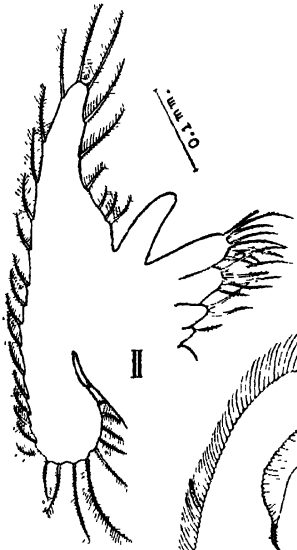
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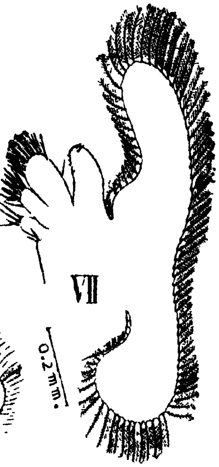
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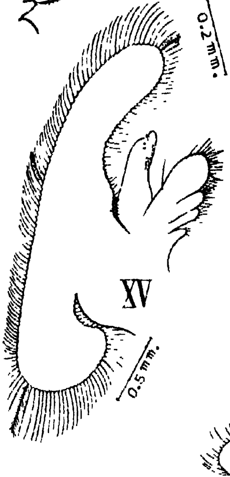
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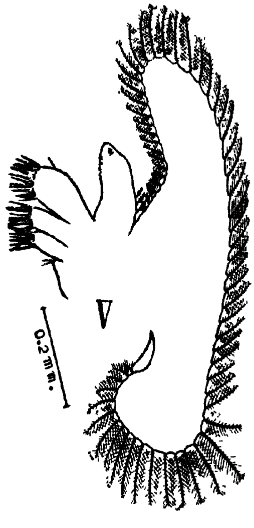
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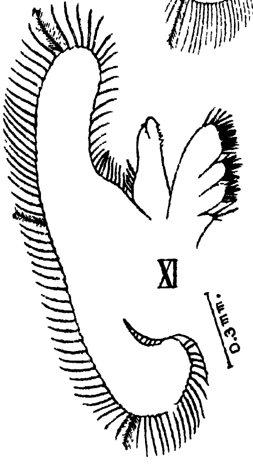
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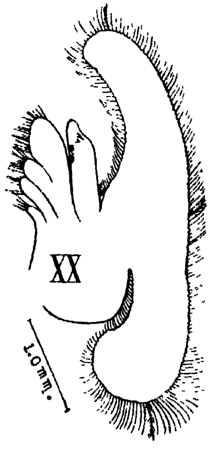
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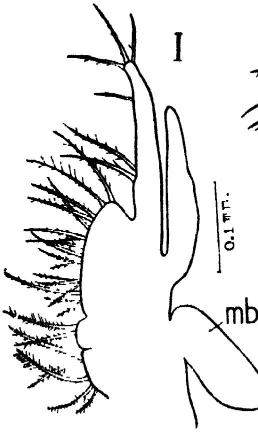

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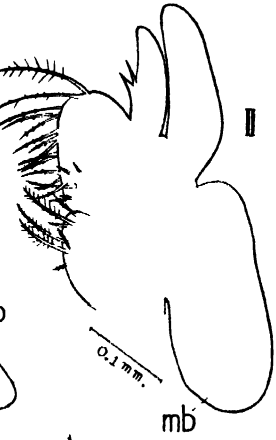

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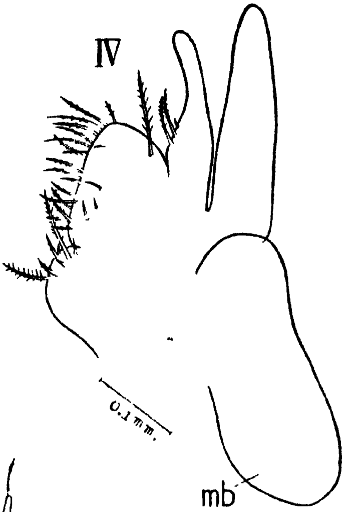

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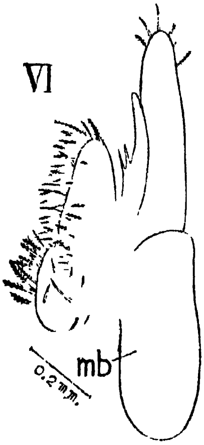

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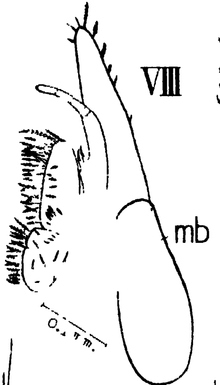

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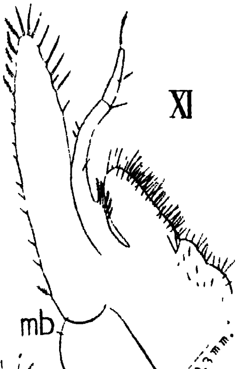

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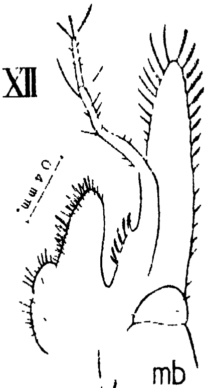

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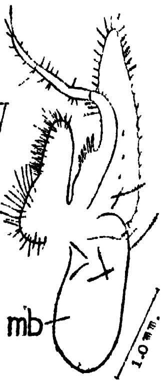

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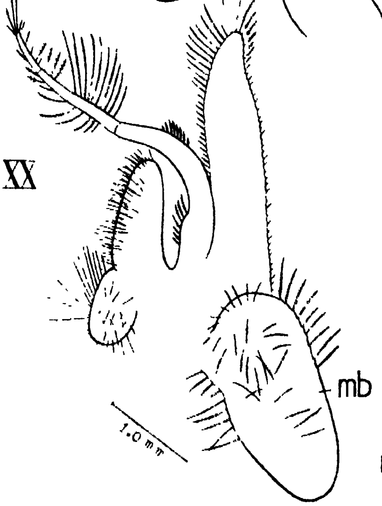

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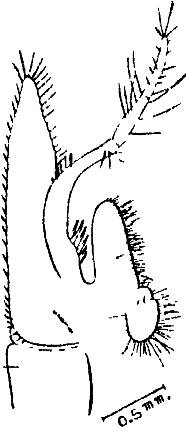

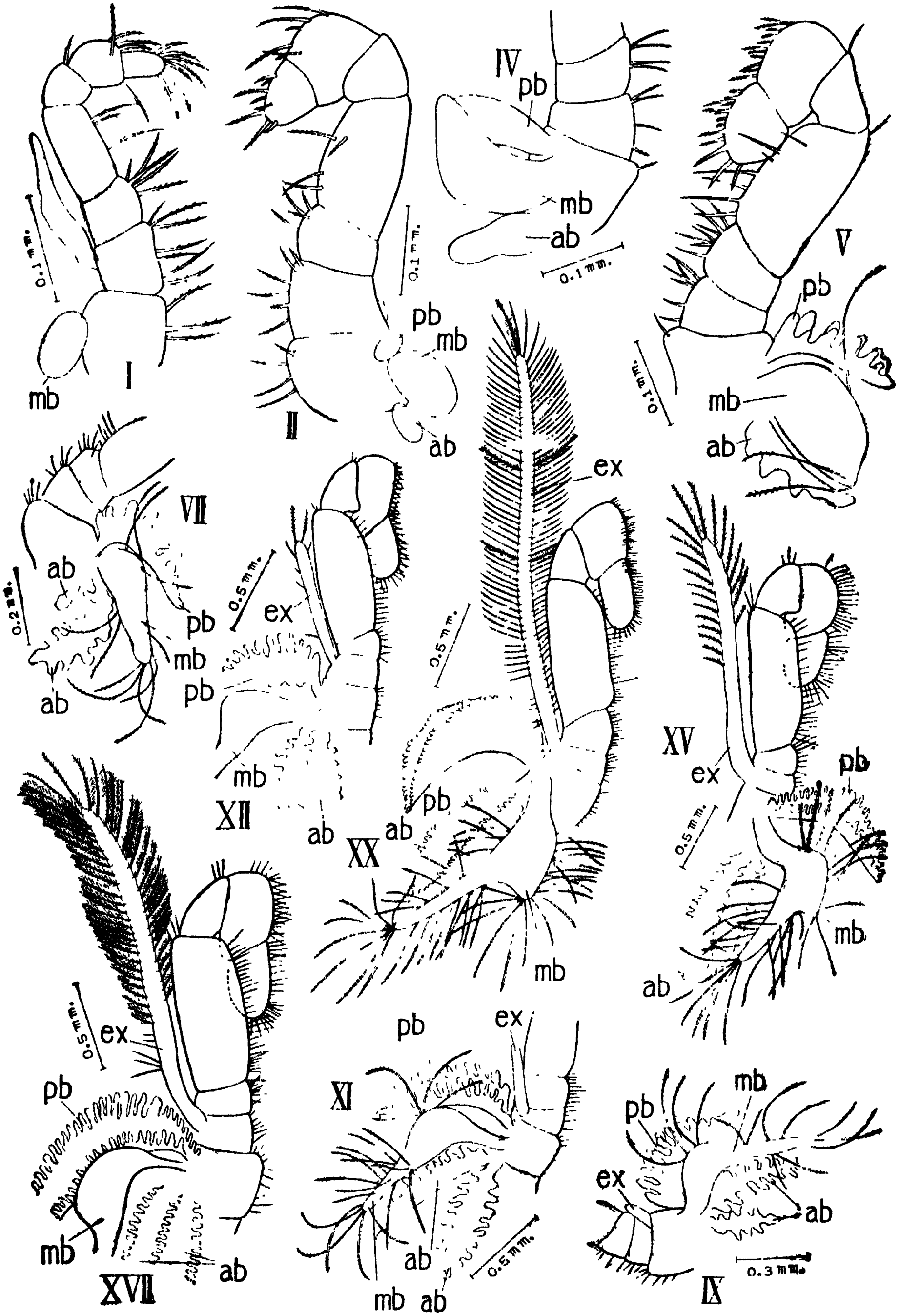
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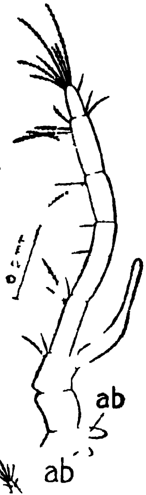

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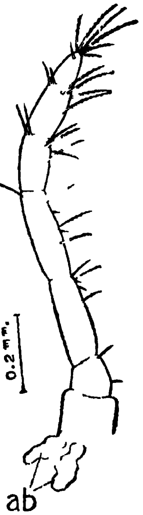

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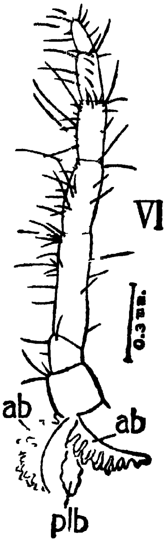

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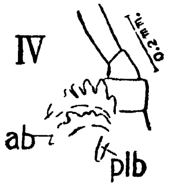

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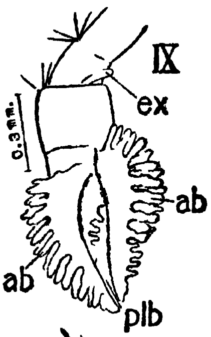

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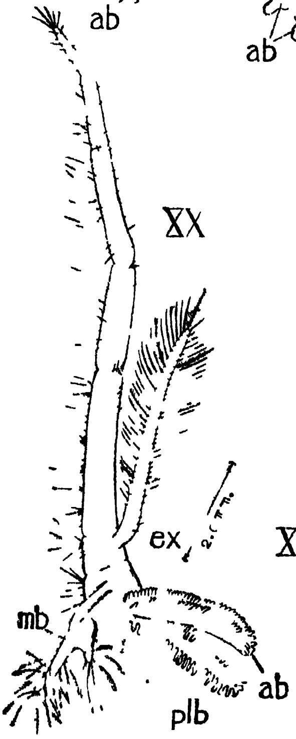

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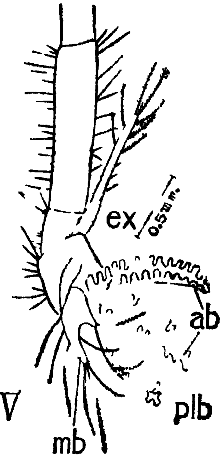

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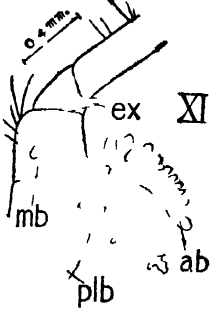

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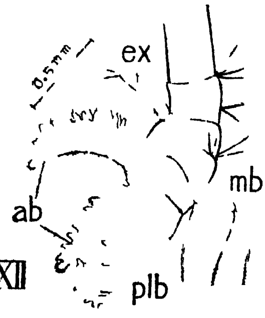

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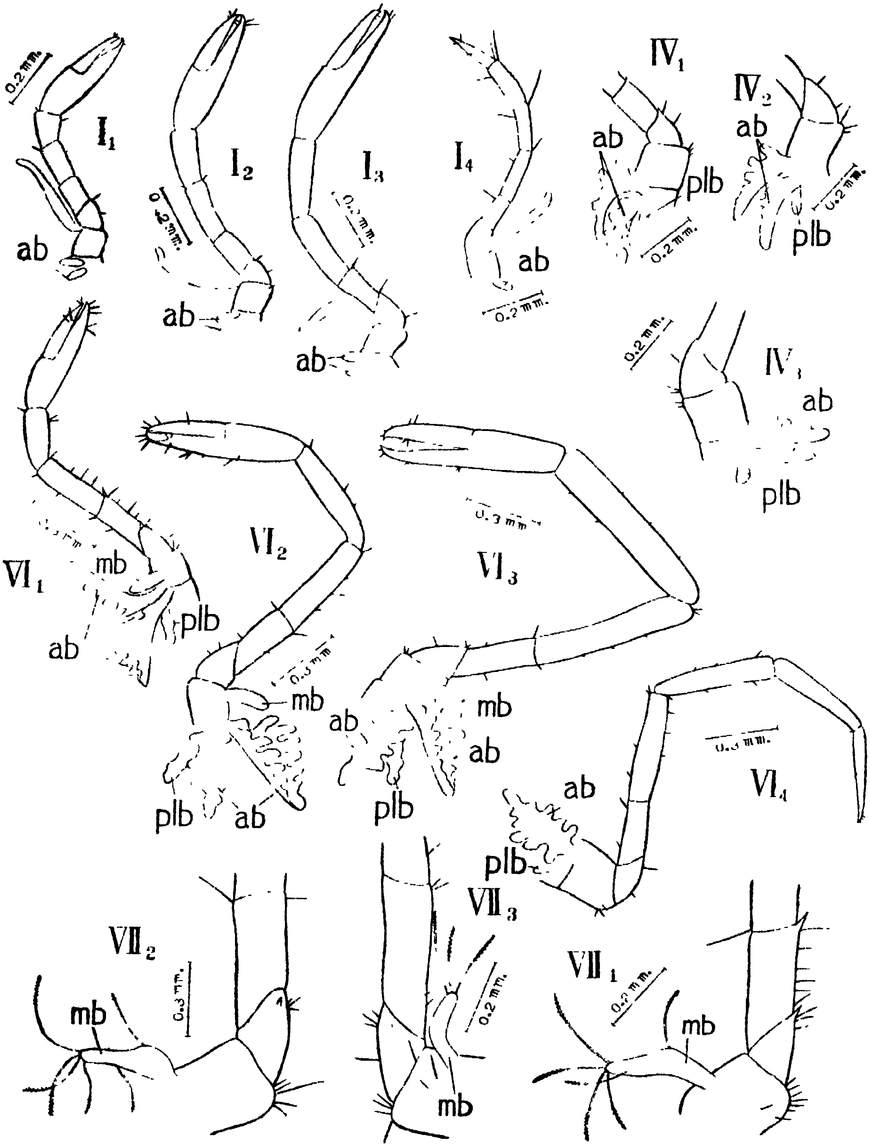
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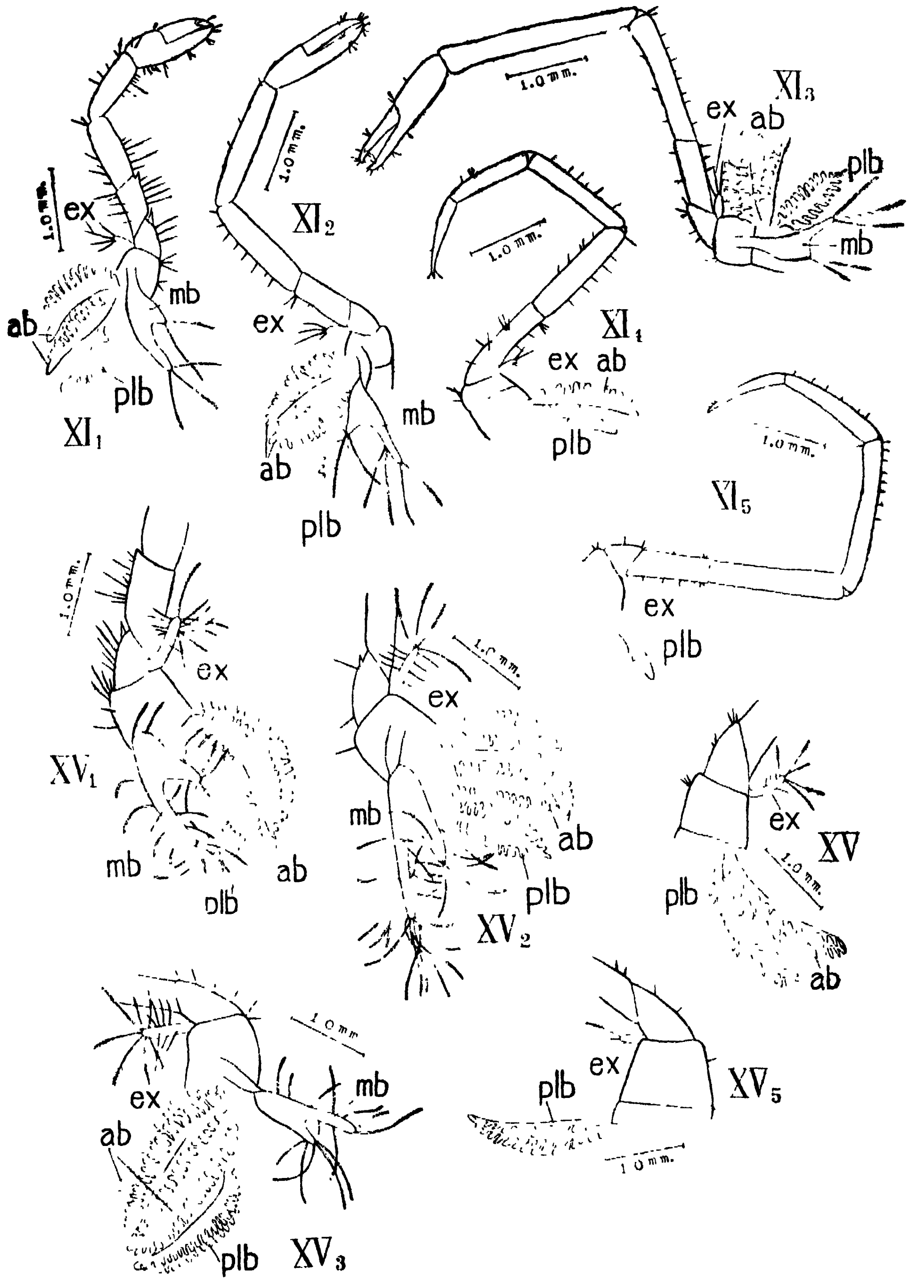
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3. Über die Leber, die Gallengänge und den Pankreasgang von *Delphinus* mit vergleichend-anatomischen Bemerkungen

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(Mit 1 Text-figur)

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I. Einleitung

Seit vielen Jahren habe ich unter Prof. Dr. T. Sindo Untersuchungen über die Morphologie des Gallengangsystems der Vertebraten angestellt, wobei ich bemerkt habe, dass die Form und Lappenzahl der Leber nach Tierarten verschieden sind und zwar nach ihren Einteilungen ein System zeigen.

Dieser Befund hat mich glauben lassen, dass es von dem Standpunkte der vergleichenden Anatomie nicht ohne Bedeutung sei, die verschiedenen Leberformen in Schemata zu bringen und diese mit der heutigen Tiersystematik vergleichend auseinander zu setzen.

Bei dieser Forschung habe ich von Prof. Dr. Osamu Emoto in der Veterinären Abteilung der Landwirtschaftlichen Fakultät der Kaiserl. Universität zu Tokyo viele, kostbare Materialen geschenkt bekommen. Auch sein Freund Prof. Ikusaku Amemiya in der Fischereiabteilung derselben Fakultät, hat mir Leber und Magen eines ausgewachsenen *Delphinus longirostris* Cuvier liebenswürdigerweise gesandt. Hiermit drücke ich beiden Herren meinen herzlichsten

Dank für ihre grosses Entgegenkommen aus.

Über die Cetaceen gibt es zwar viele anatomische Untersuchungen, aber es scheint uns noch zweifelhaft zu sein, welche systematische Stellung sie einzunehmen scheint. Ausserdem gibt es sehr wenig anatomische Beschreibungen über ihre Leber und Gallengänge.

Die Klarstellung der Form der Leber, der Gallengänge und des Pancreasganges vom *Delphinus* würde unter diesen Umständen zur Erforschung derselben Organe nicht nur von der Odontoceten, sondern auch von der Cetaceen überhaupt mehr oder weniger beitragen. Auch würden dadurch die Beziehungen der Cetaceen zu anderen Mammalien von selbst klar werden, und es könnten noch gewisse Anhalte zum Bestimmen der systematischen Stellung der Cetaceen gewonnen werden.

Ich habe die Leber, den Gallen- und den Pancreasgang vom *Delphinus* genau untersucht und gefunden, dass sie mit den erwähnten Organen von der Pecoren unter Ruminanten, vor allem aber vom *Cervus*, bei welchem die Gallenblase fehlt, eine auffallende Ähnlichkeit zeigen. Neuerdings hat die vergleichende Anatomie von der Leber, dem Gallen- und Pankreasgang S. A. Siwe in „Handbuch der vergleichenden Anatomie der Wirbeltiere. Bd. III, von L. Bolga u. a. (1937)" genau erörtert. Deshalb unterlasse ich weitere literalische Angaben.

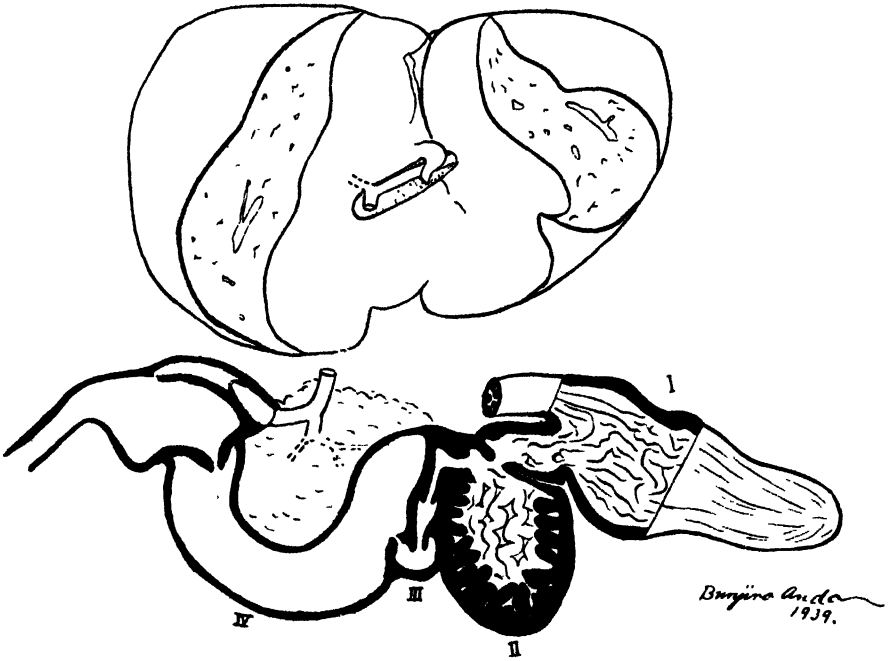
II. Form der Leber von *Delphinus*

Die Leber des *Delphinus longirostris* Cuvier ist von einer nach rechts und links ausgedehnten, plattelliptischen Gestalt und hat die zwei Flächen: Facies diaphragmatica und Facies visceralis. Ein wenig links von der Mitte des Margo ventralis befindet sich die seichte Incisura hepatis; dahinter folgt auf der Fac. diaphragmatica das Lig. falciforme hepatis, auf der Fac. visceralis die Fossa venae umbilicalis. Die Porta hepatis prägt sich rechts am Ende der Fos. v. umbilicalis als eine Querfurche aus. Die Fos. ductus venosi ist eine seichte Längsfurche, welche hinter dem linken Ende der Porta hepatis liegt, d. h. hinter der Fos. v. umbilicalis folgt, und lässt hier die Haftlinie der Lig. venosum (Arantii) erkennen. Dasjenige nämlich, was man Fossa sagittalis (sinistra) nennen kann, ist fast vollkommen ausgeprägt.

Diese Fossa sagittalis sinistra und Ligamentum falciforme hepatis zeigt die Grenze zwischen den beiden, d. h., dem rechten und dem linken Lappen.

Ferner fehlt diesem Tiere die Gallenblase, wie auch die Fossa vesicae felleae, so dass man auf der unteren Fläche des Lobus dexter den Lobus quadratus nicht klar abgrenzen kann. Auch lässt sich hinter dem rechten Ende der Porta hepatis keine Fossa venae cavae erkennen, welche also aus der Leber dieses Tieres Fossa sagittalis dextra gänzlich verschwunden ist. Der Lobus caudatus ist auch nicht nur ganz unerkennbar, sondern auf der unteren Fläche des Lobus dexter ist auch nirgend eine Erhöhung, welche einen Processus caudatus andeutet zu finden. Diese Fläche ist im ganzen durch den Druck der IV Magenkammer etwas vertieft. Die obere Fläche der Leber ist deutlich stark vorgewölbt.

Das Charakteristikum an der Leber dieses Tieres ist, dass hinter dem linken Rande des Lobus dexter ein kleines blattförmiges Läppchen gegen das hintere Ende der Fossa v. umbilicalis und die Porta hepatis hin vorspringt. Das Ende dieses Läppchens ist zugespitzt; die Basis desselben haftet etwas erweitert am linken Rande des rechten Lappens.



Delphinus, die Leber und der Magen

III. Form der extrahepatischen Gallengänge von *Delphinus*

Weil dem *Delphinus* die Gallenblase fehlt, hat er auch keinen sog. Ductus cysticus. Der Ductus choledochus ist daher durch die Vereinigung der 2 Ducti hepatici miteinander gebildet; die intrahepatischen Gallengänge des rechten und linken Leberlappens sammeln sich schliesslich in je einen dicken extrahepatischen Ductus hepaticus. Der linke Ductus hepaticus kommt nahe dem linken Ende der Porta hepatis und entlang der Vena portae aus der Leber hervor. Er verläuft längs der Porta hepatis nach rechts und trifft mit dem ganz kurzen rechten Ductus hepaticus am rechten Ende derselben Y-förmig zusammen, wodurch Ductus choledochus entsteht. Der rechte Ductus kommt ausserhalb der Leber kaum zum Vorschein und ist etwas dünner als der andere.

Der Ductus choledochus, welcher vom rechten Ende der Porta hepatis abgeht, nimmt nach kurzem Verlauf hinten abwärts an seiner linken Wand den Ductus pancreaticus auf. Von dieser Vereinigsstelle knickt er stark nach rechts ab, und dringt bald in die Darmwand der Ampulle am Anfangsteil des Duodenum hinein. Der Ductus choledochus ist dicker als die beiden Ducti hepatici; sein ganzer Verlauf aber ist verhältnismässig kurz, und sein oberer Teil ausserhalb der Darmwand und sein intramuraler Teil sind fast gleich lang. Die Stelle, an der der Ductus pancreaticus mit ihm zusammentrifft, liegt ungefähr in der Mitte seines oberen Extraintestinalen Teiles.

Um die Form des intramuralen Teiles des Ductus choledochus zu beschreiben, muss man zuerst auf die besondere Gestalt des Duodenum hinweisen. Das Duodenum des *Delphinus* folgt der IV Magenkammer; sein Anfangsabschnitt erweitert sich gross ampullär und sie ist viel weiter als die IV Kammer. Der feigenförmig stark angeschwollene Teil ist nächst dem Pylorus zu finden. Am Pylorus ist eine dicke trichterförmige Falte vorhanden, welche sich nach der IV Magenkammer richtet. Das untere Ende der Ampulle wird schmal wie gewöhnliche Dünndarmlumen.

Der Ductus choledochus dringt an der oberen Wand der duodenal Ampulle von der Pylorus-seite aus analwärts in dieselbe hinein, und mündet, nachdem er dieselbe Richtung behaltend durch die Darmwand hindurch verläult, erst in die Darmhöhle ein. Die im allgemeinen dicke Wand des Duodenum ist dort, wo sie Ductus choledochus verlaufen lässt, besonders dick geworden. Ihre Tunica muscuralis auffallend stark entwickelt, wie die Darmwand, welche längs des Verlaufes des Ductus choledochus, so wohl nach aussen wie auch nach innen, eine Erhöhung zeigt.

In dem inneren Hohlraum des intramuralen Teiles vom Ductus choledochus, versieht es sich ungefähr in der Mitte desselben mit einer trichterförmigen Falte, welche distalwärts gerichtet ist. Das Lumen des Ductus choledochus ober- und unterhalb dieser Falte sind beiderseits ein wenig erweitert. Vereinigt sich der Ductus choledochus auch mit dem Ductus pancreaticus, so ist oberhalb dieser Vereinigungsstelle der Ductus choledochus gleichmässig gross und unterhalb derselben im Gegenteil spindelförmig ausgedehnt.

Die Endstrecke des Ductus choledochus, welche sich von der Vereinigungsstelle des Ductus choledochus mit dem Duct. pancreaticus aus bis zur obengenannten trichterförmigen Falte erstreckt ist im ganzen spindelförmig erweitert. Die unterhalb der Falte sich befindende Erweiterung ist wie eine lange Vase gestaltet und das Vasenende ist in der gewöhnlichen Zeit verschlossen.

IV. Form des Pankreasganges von *Delphinus*.

Wie oben gesagt, wird der Ductus pancreaticus des *Delphinus* ungefähr in der Mitte des Ductus choledochus ausserhalb des Darmes auf der linken Seite desselben aufgenommen. Dabei ist es besonders zu beachten, dass die beiden Gänge von der entgegengesetzten Richtung kommend fast in gerader Linie zusammentreffen, und dass infolgedessen der sozusagen gemeinsame Gang, welcher von der Vereinigungsstelle der beiden beginnt, bei beiden fast rechtwinkelig abläuft. Über das oben erwähnte Verhalten ist mit anderen Worten auch zu sagen, dass der D. pancreaticus an der Knickstelle des rechtwinkelig gebogenen D. choledochus in den letzteren hinein fliesst.

Es gibt leider kein Mittel dazu, den Ausflussmechanismus der Galle und des Pankreassaftes bei diesem Tiere zu beobachten, aber die Tatsache, dass bei ihm, dem die Gallenblase fehlt. der intramusculäre gemeinsame Gang mit einer trichterförmigen Falte versehen ist, scheint im Vergleich zu den Gallengängen der anderen Mammalien bei denen die Gallenblase fehlt, für den Ausflussmechanismus von grosser Bedeutung zu sein.

V. Vergleichende Betrachtungen

A. Vergleichung der Leberformen

1) Schema der Leberlappen der Vertebraten.

Ich habe die Lebern der Vertebraten nach ihren äusseren Formen und Lappenzahlen, in folgende Schemata gebracht:

Nach meinem Schema sind die Lebern in sechs Arten näml. von der 6-, 5-, 4-, 3-, 2- und 1-lappigen eingeteilt. Es gibt keine Leber, welche aus mehr als 6 Lappen besteht; 6 ist das Maximum. Wenn auch die Leber des *Zalophus lobatus* der Pinnipedien und die des *Camelus* der Tylopoden in unzählige grössere und kleinere Lappen eingeteilt zu sein scheinen, so sind sie doch nicht als mehr als 6 zu erklären, denn durch beliebige Incisuren zerfällt bei diesen jeder einzelne Lappen der 6 nur wieder.

Da bei den Carnivoren im allgemeinen sei es Fissipedien wie auch Pinnipedien, die Leber als Regel 6 lappig ist, habe ich diese als Grundtypus aufgenommen, und andere gefundene 6-lappigen Lebern nehme ich als die diesen Grundtypus behaltende, und 5-, 4-, 3-, 2- und 1-lappige als durch Vereinigung der 6 Lappen entstandene an.

Für die Bezeichnungen der einzelnen Lappen habe ich die Namen: Lobus lateralis sinister, Lobus medialis sinister, Lobus quadratus, Lobus medialis dexter, Lobus lateralis dexter und Lobus caudatus, nach W. Ellenberger und H. Baum gebraucht.

Stelle ich nun nach den Leberformen und Lappenzahlen vorläufig eine Tabelle auf, so sind 7 Systeme darauf zu ersehen.

Bei den Mammalien:

I. Carnivoren-System: Grund-typus (6-lappig)

II. Primaten-System: (6–2-l.)

III. Ungulaten-System: (6–3-l.); Perissodactylen (6-l.), Artiodactylen (Non-Ruminanten (5-l.), Ruminanten (6–3-l.)

IV. Rodenten-Insectivoren etc. System: (6–3-l.); Insectivoren (6-l.) Rodenten (6–5-l.), Macropodiden (5-l.), Monotremen (5-l.), Chiropteren (5–4-l.), Edentaten (3-l.)

Bei den Non-Mammalien:

V. Sauropsiden-System: (1–2-l.); Reptilien (1–2-l.) und Aves (2-l.)

VI. Amphibien-System: (1–3-l.); Urodelen (1-l.) und Anuren (3-l.)

VII. Pisces-System: noch wenig bestätigt.

Vergleicht man die Leber des *Delphinus* mit denen auf der obigen Tabelle, so hat sie mit der der Ungulaten die grösste Ähnlichkeit; deshalb erkläre ich hier bequemlichkeitshalber vor allem nur die Leber der Ruminanten.

2) Schema der Leberlappen der Ruminanten.

I. Unter Ruminanten: Tylopoden 6-lappiger Lebertypus

II. Unter Ruminanten: Pecoren 3-lappiger Lepertypus

A. Gallenblase erhaltener Lebertypus

a) Drei lappiger Lebertypus, bei welchem Processus papillaris des Lobus caudatus erscheint: *Capra hircus*, *Capricornis crispus*

b) Drei lappiger Lebertypus, bei welchem Processus papillaris zurücktritt: *Bos taurus*, *Anoa depressicornis*

B. Gallenblase nicht erhaltenen Lebertypus, (ohne Fossa und Incisura vesicae felleae,).

a) Drei lappiger Lebertypus, bei welchem Processus papillaris des Lobus caudatus erscheint: *Muntiacus reevesii*

b) Drei lappiger Lebertypus, bei welchem Processus papillaris verschwunden ist: *Cervus*

C. Gallenblasenrest erhaltener 3-lappiger Lebertypus, bei welchem Processus papillaris des L. caudatus zurücktritt: *Giraffa cameleopardalis*

3) Vergleichung der Leberform von *Delphinus* mit denen der anderen Mammalien.

Sucht man nun unter den Lebern anderer Tiere solche, die der des *Delphinus* ähnlich geformt sind, so sind es die Lebern des *Cervus* und der Hylobatinae.

Wenn man bloss die Tatsache, dass die Leber des *Delphinus* nur zwei lappig gestaltet ist, in Betracht zieht, so ist diese der der Hylobatinae viel ähnlicher als der des *Cervus*. Doch ist die Leber der Hylobatinae immer mit Gallenblase in der Fossa vesicae felleae versehen, wie der Lobus quadratus somit klar abgegrenzt ist. Ferner ist auch eine Erhöhung, welche dort Processus caudatus andeutet, klar wahrgenommen. Man kann also die Leber der Hylobatinae mit der des *Delphinus*, morphologisch nicht ohne weiteres gleichsetzen.

Wie oben gesagt, ist die Leber des *Cervus* ohne Gallenblase in drei Lappen (L. dexter, L. sinister und L. caudatus) eingeteilt, und infolgedessen fehlt natürlich auf ihrer unteren Fläche die Fossa vesicae felleae. In dieser Beziehung ist sie der Leber des *Delphinus* sehr ähnlich. Der einzige Unterschied zwischen beiden Lebern aber besteht nur darin, dass beim *Cervus* der Processus caudatus sich von der unteren Fläche des Lobus dexter als ein Lappen getrennt zeigt, während derselbe beim *Delphinus* gänzlich in anderen verborgen ist. Das heisst; wenn die Leber des *Cervus* den Processus caudatus nicht versehen liesse, so wäre sie von ganz gleichem Typus wie die Leber des *Delphinus*. Die untere Fläche der *Delphinus*-leber lässt keine Erhöhung, welche wie bei der Leber der Hylobatinae einen verborgenen Processus caudatus andeutet, erkennen. Ob sich beim *Delphinus* der Processus caudatus mit der unteren Fläche des Lobus dexter substantiell vereinigt hat und dort verborgen bleibt, oder ob er geschrumpft verschwunden ist, das lässt sich nicht leicht entscheiden. Denn es gibt unter den Pecoren solche Tiere, bei denen der Processus caudatus wie bei der *Anoa depressicornis* merklich geschrumpft ist. Da aber von meinem Standpunkte aus von der Abnahme der Lappenzahl nur in dem Falle, wo sich die Lappen substantantiell vereinigt haben, die Rede sein kann, so wäre es nicht eben unrecht, auch die Verschwundenheit des Processus caudatus beim *Delphinus* so aufzufassen, dass derselbe sich mit der unteren Fläche des Lobus dexter substantiell vereinigt hat und dort verborgen bleibt.

Aus diesen morphologischen Gründen steht die Leber des *Delphinus* unter vielen Mammalien zu der des *Cervus* in innigster Beziehung. Die Auffassung, dass diese Lebern einander ähnlich geformt bald den 3-lappigen Typus wie beim *Cervus*, bald den 2-lappigen wie beim *Delphinus* angenommen haben, je nachdem der Processus caudatus des Lobus caudatus zum Vorschein gekommen ist oder nicht, würde genehmigt werden in Anbetracht, dass unter den Primaten der 3 lappige Lebertypus vom *Anthropithecus niger* dadurch entstanden ist, dass ausser dem rechten und linken Lappen der Lobus caudatus zum Vorschein gekommen ist, und der 2-lappige von der Hylobatinae dadurch, dass ausgenommen die oben erwähnten zwei Lappen der Lobus caudatus seine Gestalt nicht zeigt.

Demnach kann man den Transformationsprozess der Leberform vom Grundtypus näml. von dem 6-lappigen-Typus der Carnivoren, bis zum 2-lappigen des *Delphinus* als wie folgt annehmen:

Zuerst kommt eine Stufe für den 5-lappigen Typus des *Sus* (Non-Ruminanten), nachdem der Grundtypus so wie bei *Equus* (Perissodactylen) auch bei *Camerus* (Ruminanten) noch als 6-lappiger seine Herrschaft gehalten hat, folgt dann der 3-lappige Typus bei den Pecoren, wie z. B. beim *Cervus* mit der 3-lappigen Leber ohne Gallenblase, und endlich entwickelt sich der 2-lappige Typus des *Delphinus* durch Verschwinden vom Lobus caudatus, der als ein Lappen stand.

Solcher Transformationsprozess der Leberform von den Ungulaten bis zu den Odontoceten scheint mir morphologisch sehr bedeutungsvoll zu sein, wenn ich ihn mit dem Befund vergleiche: dass bei den Primaten die Leber des *Nycticebus tardigradus* (Prosimiae) in 6-lappen eingeteilt den Grundtypus bildet, während die Lebern der *Ateles* und der *Hapale* unter den Platyrhinen wie auch Macaci und Cercopitheci unter den Catarhinen vom 5-lappigen Leber Typus sind, die des *Pygatherix obscurus* und des *Papio* unter den Simnopithecinae vom 4-lappigen, die des *Anthropopithecus niger* vom 3-lappigen, die Menschenleber vom unvollständigen 3-lappigen, bei welchem Processus caudatus zurücktritt. Und die Leber der Hylobatinae von 2-lappigen ist.

Deshalb möchte ich den *Delphinus* unter dem Ungulaten-System einordnen und dieses als Odontoceten-Ungulaten-System benennen.

Wenn man nun die beiden Systeme, das Odontoceten-Ungulaten-System und das Primaten-System, vergleicht, so lassen sie fast gleiche regelmässige Verminderung der Leberlappenzahl, 6, 5, 4, 3, 2 erkennen, und die Stellung der *Delphinus*-leber im Odontoceten-Ungulaten-System entspricht wohl der der Hylobatinae im Primaten-System.

So ist die Leber des *Delphinus* wie die der Hylobatinae durch die Vereinigungen der einzelnen Leberlappen des Grundtypus entstanden, der linke Lappen nämlich durch die Vereinigung des Lobus lateralis sinister mit dem Lobus medialis sinister, und der rechte durch die des Lobus quadratus mit dem Lobus medialis dexter, Lobus lateralis dexter und Lobus caudatus.

B. Vergleichung der extrahepatischen Gallengänge

1) Schema der extrahepatischen Gallengänge der Vertebraten.

Ich habe die Formen der extrahepatischen Gallengänge der Vertebraten schematisch zusammenfassend in zwei Haupttypen eingeteilt:

I. Typus mit typisch geformten Ductus choledochus und

II. Typus mit nicht typisch geformten Ductus choledochus, (bei welchem der Ductus hepaticus in seinem oberen Teile ausserhalb des Darmes mit dem Ductus cysticus nicht zusammenkommt und zwar beide einzeln in die Darmwand eindringen, so dass der Ductus choledochus nicht typisch geformt ist. Wir sehen den I Typus bei Mammalien, Amphibien und Pisces, und den II bei Aves und Reptilien.

Die Gallengänge von Mammalien unterscheidet man auch nochmal in 2 Gruppen:

1. Mit Gallenblase; bei welchem der Ductus choledochus durch die Vereinigung des Ductus cysticus mit dem Ductus hepaticus entstanden ist. 2. Ohne Gallenblase; bei welchem der Ductus choledochus durch die Vereinigung der Ducti hepatici miteinander entstanden ist. In dieser Abhandlung wird der zweite gallenblasenlose Typus bei den Mammalien nur zum Gegenstande der Erklärung gewählt. Unter diesem Typus finden sich zwei Arten vor: die eine, bei der beide Ducti hepatici, der rechte und der linke, Y-förmig in den Ductus choledochus übergehen, und die andere, bei der mehrere Ducti hepatici baumzweigförmig zusammenkommen. Der erstere sei der Gabeltypus, und der letztere der Baumzweigtypus genannt.

Zum Gabeltypus gehören die Gallengänge des *Camelus*, *Muntiacus reevesii* und *Cervus*, und zum Baumzweigtypus die der Tiere ohne Gallenblase unter den Rodenen, (d. h. des *Sciulus lis*, des *Rattus*, der *Bandicota nomorivaga* (Hodyson) (Murinae) und die des *Equus*.

2) Vergleichung der extrahepatischen Gallengänge von *Delphinus* mit denen der anderen Mammalien.

Die extrahepatischen Gallengänge des *Delphinus* gehören selbstverständlich zum Gabeltypus ohne Gallenblase, und in dieser Hinsicht sind die gallenblasenlosen wie der *Camelus*, *Muntiacus reevesii* und *Cervus* mit ihm als gleichartig zu betrachten.

In Wirklichkeit ist bei diesen vier Tieren der Ductus choledochus auf gleicher Weise entstanden. (Der Ductus choledochus ist durch die Vereinigung der zwei Ducti hepatici miteinander entstanden und gegabelt.)

Beim *Cervus* ist nicht nur die Längen-, sondern auch die Dickenproportion zwischen verschiedenen Teilen des Ductus choledochus fast gleich wie die beim *Delphinus*, und man kann sagen, dass unter den extrahepatischen Gallengängen der Mammalien die des *Cervus* denselben des *Delphinus* am meisten ähnlich sind. Und so gilt es, diese beiden noch eingehender miteinander zu vergleichen.

Die morphologischen Unterschiede zwischen beiden sind folgendes:

1. Beim *Cervus* verläuft der ganze Ductus choledochus in gleicher Richtung wie der Ductus hepaticus sinister, fast auf einer geraden Linie mit diesem, von vorn links schräg nach hinten rechts. Beim *Delphinus* ist der obere Teil des Ductus choledochus ausserhalb des Darmes an der Stelle, wo dieser Ductus den Ductus pancreaticus in sich aufnimmt, rechtwinklig stark nach rechts gebogen.

2. Beim *Cervus* biegt sich das Duodenum U-förmig, wo es den Ductus choledochus in sich aufnimmt, und dieser dringt an seiner dritten Krümmung in die Darmwand hinein.

Beim *Delphinus* bildet der Anfangsteil des Duodenum eine grosse Ampulle, zeigt aber keine besondere Krümmung, und der Ductus choledochus dringt gegen die obere Wand dieser Ampulle distalwärts in die Darmwand hinein; d. h. das Duodenum des *Cervus* und des *Delphinus* sind da, wo sie den Ductus choledochus in sich aufnehmen, anders geformt.

3. Beim *Cervus* zeigt der Ductus choledochus da, wo er in die Darmwand hineindringt, eine Verengung, welche von der Darmwand ausgeübt entstanden ist, was die Existenz der besonderen Krümmung des Duodenum zur Ursache hat. Die Höhle des Ductus choledochus lässt nirgends eine klappenförmige Falte erkennen.

Dagegen zeigt der Ductus choledochus des *Delphinus* keine Verengung, wo er in die Darmwand hineindringt, sondern ist erweitert und lässt unten ungefähr in der Mitte der Pars intestinalis eine bedeutende trichterförmige, klappenförmige Falte erkennen.

Die Verengung der Pars intestinalis des Ductus choledochus vom *Cervus* und die trichterförmige Falte in derselben des *Delphinus* sind morphologisch verschieden, physiologisch aber scheinen sie von gleicher Bedeutung zu sein. Denn wie beim *Cervus* ober- und unterhalb der Verengung, so auch beim *Delphinus* an der trichterförmigen Falte, zeigt der Ductus choledochus leichte spindelförmige Erweiterung.

4. Beim *Cervus* ist die Wand der Gallengänge überall sehr dünn, desgleichen die des Duodenum. Beim *Delphinus* dagegen ist die Wand der Gallengänge wie auch des Duodenum sehr dick.

5. Beim *Cervus* ist die Ausmündung des Ductus choledochus so geformt, dass man vermuten muss, sie würde im lebenden Körper nie ganz geschlossen werden. Die Ausmündung des Ductus choledochus des *Delphinus* dagegen ist fast verschlossen.

6. Die Entfernung vom Pylorus bis zur Mündung des Ductus choledochus ist beim *Delphinus* sehr nahe, beim *Cervus* dagegen verhältnismässig weit.

Die morphologischen Ähnlichkeiten zwischen den Gallengängen des *Cervus* und des *Delphinus* sind folgende:

1. Die beiden Ducti hepatici sind dick, und zwar der linke etwas dicker als der rechte; der rechte ist kurz, der linke weit länger als der erstere. Beide kommen Y-förmig zusammen und gehen in den Ductus choledochus über.
2. Der Ductus choledochus ist etwas dicker als die beiden Ducti hepatici.
3. Der obere Teil des Ductus choledochus ausserhalb des Darmes ist fast gleich lang wie die Pars intestinalis.
4. Beide Teile (Pars intestinalis und P. extraintestinalis) zeigen je eine leichte spindelförmige Erweiterung.
5. Ungefähr in der Mitte des oberen Teiles des Ductus choledochus ausserhalb des Darmes kommt der Ductus pancreaticus mit ihm zusammen.

Alles zusammengefasst: die extrahepatischen Gallengänge des *Delphinus* und des *Cervus* sind im wesentlichen einander sehr ähnlich, und man kann sagen, dass die beiden vom gleichen Typus seien, obgleich sie einige wenig bedeutende Verschiedenheiten zeigen.

C. *Vergleichung des Ductus pancreaticus*
(Vergleichung der Vereinigungsformen des Ductus
choledochus mit dem Ductus pancreaticus.)

1) Schema des Ductus pancreaticus der Mammalien

Bei den Mammalien findet man hauptsächlich einen Ductus pancreaticus der in Duodenum mündet. Der Hauptpancreasgang vereinigt sich bald mit dem Ductus choledochus oder mündet später ganz dicht anliegend an der Mündung des letzteren in die Darmhöhle hinein. Somit erkläre ich weiter etwas eingehend über den ersteren Fall, bei welchem sich der Ductus pancreaticus mit dem Ductus choledochus vereinigt.

A) Der eine Fall, bei dem sich der Ductus pancreaticus innerhalb der Darmwand mit der Pars intestinalis des Ductus choledochus vereinigt. Die Höhe der Vereinigungsstelle ist je nach der Tiere verschieden, aber es ist hier nicht näher zu erklären.

B) Der andere, bei dem sich der Ductus pancreaticus ausserhalb des Darmes mit dem Ductus choledochus vereinigt. Diese Vereinigungsstelle liegt zwar nach Tierarten in verschiedenen Höhen, doch wird hierin eine ungefähre Regelmässigkeit beobachtet.

1. Eine niedrige Vereinigungsstelle. Der Ductus pancreaticus vereinigt sich mit dem Ductus choledochus in dem unteren Eindrittel der Pars extraintestinalis desselben z. B. bei *Rattus* und Makropoden (Phytophagen).
2. Eine mittlere Vereinigungstelle. Bei dies vereinigt sich der Ductus pancreaticus mit dem Ductus choledochus ungefähr im mittleren Drittel der langen Pars extraintestinalis desselben.

Bei den Pecoren mit Gallenblase kommt der Ductus pancreaticus mit dem Ductus choledochus ein wenig unterhalb der Mitte der kurzen P. extraintestinalis desselben; beim *Cervus*, welchem die Gallenblase fehlt, fast in der Mitte. Bei der *Giraffa cameleopardalis* ist die Vereinigungsform der beiden Gänge der des *Cervus* ähnlich.

3. Eine höhere Vereinigungsstelle. Die Vereinigungsstelle befindet sich im allgemeinen in der Gallenblasenhalsgegend.

Diesen Typus haben die Hystricidae, *Hystrix cristata*, und *Erethizon dorsatus*. Weil bei diesen Tieren zwei Ducti hepatici dicht an der Halsgegend der Gallenblase mit dem minimal kurz gewordenen Ductus cysticus zusammenfliessen und somit unmittembar der Ductus choledochus entsteht, so hat sich kein Ductus cysticus bei ihnen gebildet; sie sind von einer besonderen Art, welche die Gallenblase und doch keinen Ductus cysticus besitzt. Ductus pancreaticus wird bei ihnen entweder in den Anfangsteil des Ductus choledochus (*Hystrix cristata*) oder in die Höhle des Halses der Gallenblase (*Erethizon dorsatus*) aufgenommen.

Bei den Mammalien wird also die Tendenz bemerkt, dass sich die Vereinigungsstelle beider Ducti stufenweise von unten nach oben verschiebt: bei einigen Mammalien vereinigen sich beide Ducti überhaupt nicht und sie münden einzeln in die Darmhöhle ein, dann gibt es solche, bei denen sie sich unten in der Darmwand (in der Nähe der Darmhöhlen-mündung) vereinigen; und dann solche, bei denen sie sich etwas oben ausserhalb des Darmes vereinigen; und zuletzt solche, bei denen der Ductus pancreaticus noch weiter oben in die Halsgegend der Gallenblase aufgenommen wird.

2) Vergleichung des Ductus pancreaticus von *Delphinus* mit denen der anderen Mammalien.

Die Vereinigungsform des Ductus choledochus mit dem Ductus pancreaticus des *Delphinus* gehört dem Typus, bei dem sich der Ductus choledochus ausserhalb der Darmwand mit dem Ductus pancreaticus vereinigt, d. h. dem Typus mit der mittleren Vereinigungsstelle, an. In dieser Beziehung gleicht der *Delphinus* genau dem *Cervus*, dem Gallenblasenlosen unter den Pecoren.

Die Unterschiede in der Vereinigungsform beider Ducti zwischen dem *Delphinus* und dem *Cervus* sind folgende:

1. Beim *Cervus* wird der Ductus pancreaticus in die rechte Wand des Ductus choledochus aufgenommen, indem er fast rechtwinklig zu diesem fällt; und der gemeinsame Gang beider Ducti behält die Richtung des eigentlichen Ductus choledochus. Beim *Delphinus* treffen der Ductus pancreaticus und der Ductus choledochus, von der entgegengesetzten Richtung kommend, zusammen, und der gemeinsame Gang beider Ducti biegt sich nach rechts, indem er rechtwinklig zu beiden fällt. Der Ductus pancreaticus des *Delphinus* wird so auf der linken Wand des Ductus choledochus in diesen aufgenommen.

Weil bei diesem *Delphinus* das Pankreas in der U-förmigen Krümmung der IV Magenkammer als ein Klump eingesetzt und hier fixiert ist, so liegt es zur linken des Ductus choledochus. Infolgedessen scheint sich der Ductus pancreaticus auf der linken Wand des Ductus choledochus mit diesem vereinigt zu haben. Das Pankreas des *Cervus* liegt äusserst unregelmässig geformt zur rechten Seite des Ductus choledochus, und heftet sich teils an diesen, nicht aber an Magen und Duodenum.

2. Beim *Cervus* ist der Ductus pancreaticus weit schmäler als der Ductus choledochus, und zwar nimmt er bis zur der Vereinigungsstelle mit letzterem

mehrere Pankreaszweige in sich auf; ausserhalb des Pankreasgewebes jedoch kommen sie nicht zum Vorschein.

Beim *Delphinus* ist der Ductus pancreaticus sehr dick; der Durchmesser desselben ist dem des eigentlichen Ductus choledochus oberhalb der Vereinigungsstelle mit dem Ductus pancreaticus fast gleich, und der eigentliche Ductus pancreaticus ist ausserhalb des Pankreasgewebes ziemlich weit zum Vorschein gekommen.

Unter vielen Mammalien, soweit ich hiermit beobachtet habe, haben keine einen relativ so dicken Ductus pancreaticus wie bei dem *Delphinus*, auch war dieser Ductus bei keinen ausserhalb des Pankreasgewebes zum Vorschein gekommen.

Kurz gesagt, die Vereinigungsform des Ductus choledochus mit dem Ductus pancreaticus beim *Cervus* und *Delphinus* sind auch als vom gleichen Typus zu betrachten.

VI. Schluss

Wie oben dargestellt, habe ich die Leber, die Gallengänge und den Pankreasgang des *Delphinus* morphologisch ganau beobachtet und gefunden, dass sie denen des gallenblasenlosen *Cervus*, morphologisch am meisten ähnlich sind. Nachfolgend drücke ich sie bei *Delphinus* auch schematisch mit Typenwörtern aus.

1. Die Leber: Gallenblase nicht erhaltener 2-lappiger Lebertypus (gehört dem Odontoceten-Ungulaten-System an).
2. Die extrahepatischen Gallengänge: Gabeltypus bei dem Gallenblasenlosen (gehört zum normal typischen, Ductus choledochus der Mammalien).
3. Der Pankreasgang: Typus, bei dem der Ductus choledochus ganz in mittlerer Höhle des letzteren ausserhalb des Darmes zusammenfliesst.

Aus diesen Forschungen möchte ich sachlich vermuten, dass der *Delphinus* den Pecoren unter den Ruminanten, vor allem aber dem *Cervus*, dem Gallenblasenlosen unter den Pecoren, irgendwie stammverwandt sei.

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4. Notes on the Development of Some Japanese Echinoids
Report IV.
Hybridization Experiments with some Japanese Echinoids

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(With 6 Text-figures)

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Introduction

In echinoids the interspecific cross is comparatively easy; in some cases even the intergeneric, interfamilial or the interordinal cross is possible. Moreover the development of the larva is so quick that the distinctive specific characteristics appear within a few days. For these reasons the echinoids have been used a great deal for the study of certain fundamental biological problems, such as the nature of interspecific distinction, the relative role played by the egg and sperm in the formation of the larva, and the relation between chromosomes and the cytoplasm in development. Thus, we already have in this field works by more than thirty different investigators. Of these the more important ones are reviewed in the next chapter.

Historical Review

Boveri (1889) divided the egg of *Sphaerechinus granularis* into nucleated and non-nucleated fragments and fertilized them with the sperm of *Echinus microtuberculatus*. He got patroclinous larvae from the non-nucleated fragments, and patroclinous and intermediate larvae from the nucleated fragments. This experiment, he thought, confirmed the decisive role played by the nuclear material in determining the filial characteristics.

Seeliger (1894) worked on the same combination, *Sphaerechinus granularis* ♀ × *Echinus microtuberculatus* ♂, but with the difference that the whole egg, and not fragments, was used in this case. The results, however, differed rather widely from what Boveri had found. The hybrids showed the characteristics of the parent species in various mixtures: some were rather patroclinous, others were distinctly matroclinous, while still others were intermediate between the parents.

Morgan (1896) carried on the cross, *Sphaerechinus* ♀ × *Echinus* ♂ or *Strongylocentrotus* ♂, and found that the skeletal structures of the hybrid larvae were largely patroclinous. The postoral rod which showed the most definite specific difference in the parent species, however, was too variable to enable him to judge whether the hybrid was patroclinous or matroclinous.

Driesch (1898, 1903) made the crosses among *Sphaerechinus*, *Strongylocentrotus* and *Echinus*, and found that the skeletons of the hybrids showed various mixtures of the parental characteristics.

Vernon (1899) declared, basing his statement on his experiment on *Sphaerechinus* ♀ × *Strongylocentrotus* ♂, that the genetic affinity of the hybrid depends much on the maturity of the sperm. In the summer months, when the maturity of the sperm is the lowest, the hybrids generally become matroclinous, whereas in the autumn and winter months, when the maturity of the sperm is the highest they become patroclinous. Thus he propounded that the genetical affinity of the hybrid depends primarily on the relative maturity of the germ cells of the parents.

Steinbrück (1902) made the cross, *Sphaerechinus* ♀ × *Strongylocentrotus* ♂, and got hybrids of three types patroclinous, matroclinous and intermediate in the same culture bowl. He stated that it was difficult to give a definite judgement on the features of the hybrid larvae, because the larvae showed high individual variability in both external form and internal structure.

Doncaster (1904) made various crossing experiments among the *Echinus*, *Strongylocentrotus*, *Sphaerechinus* and *Arbacia* species. He concluded that the maturity of germ cells exerts no direct influence upon the development of hybrid characters, and that the vitality of germ cells has no relation whatever to the inheritance of the characters of the parents. The seasonal distinction alleged by Vernon was no other than the effect of a high temperature of sea water. Thus, he was able to raise the "summer"form in winter by merely raising the temperature of sea water from 20°C to 22°C in which the hybrids of *Sphaerechinus* ♀ × *Strongylocentrotus* ♂ was cultured.

Herbst (1906) reached the same conclusion as Doncaster in his hybridization experiments with *Sphaerechinus*, *Strongylocentrotus* and *Echinus*, namely, that the seasonal distinction of the larval form is not due to the rate of maturity of germ cells but merely to the temperature of sea water. He admitted, however, the variability of the results was partly due to the structure of the egg.

Fischel (1906) obtained matroclinous hybrids mostly in his cross *Strongylocentrotus* ♀ × *Arbacia* ♂ and *Strongylocentrotus* ♀ × *Echinus* ♂, but patroclinous ones in the cross *Arbacia* ♀ × *Echinus* ♂. He also noticed in his cross, *Echinus* ♀ × *Strongylocentrotus* ♂, that, in spite of the matroclinous cell form of the hybrids, the plasm showed a patroclinous characteristic in having a granular substance in abundance as well as in its staining reaction.

Godlewski (1906) succeeded in crossing *Echinus* ♀ × *Antedon* ♂. The sperm nucleus fused with the egg nucleus. Nevertheless, it apparently exerted no influence on the larval characters which were purely matroclinous.

Kupelwieser (1909) found, in crosing the *Echinus* egg and the *Mytilus* sperm, that the sperm activated the egg to development, although the male pronucleus remained in the plasm without fusing with the egg nucleus.

Hagedoorn (1909) found in his crossing experiment of *Strongylocentrotus purpuratus* and *Strongylocentrotus franciscanus* that, although the larval characters showed high variability on almost every point, all the hybrids were largely matroclinous so far as the form of the apical end of the body rod, a comparatively stable character, was concerned.

Baltzer (1910) observed in the hybrids of *Sphaerechinus*, *Strongylocentrotus*, *Echinus*, *Arbacia*, a *Crinoid* and others, elimination of chromosomes which occurred very often. The eliminated chromosomes, according to him, were always paternal, and the hybrids became matroclinous. In the case when the elimination did not occur, intermediate hybrids were obtained. He further pointed out that the chromosome elimination was usually accompanied by some pathological features of the larvae. Similar features also resulted from the toxic action of the foreign sperm.

Tennent (1909, '10, '12, '22, '29) confirmed that in the hybridization of *Hipponoë* and *Toxopneustes*, the characters of *Hipponoë* become prevalent in either combination, when the experiment is carried out in ordinary sea water, while the result is just the reverse when the alkalinity of the water is decreased by adding some acid to the water. Thus, he concluded that the great discrepancy found among the results obtained by the previous workers was mainly due to the difference in the chemical composition of the sea water. This view of Tennent was refused by Köhler (1915 '16) on the basis of the cross between *Strongylocentrotus* ♀ × *Sphaerechinus* ♂. He held Vernon's view of the relative maturity of germ cells affecting the skeletal character. Tennent further observed that the development of hybrid larvae stopped when more than half the chromosomes were eliminated.

Loeb, King and Moore (1910) crossed *Strongylocentrotus purpuratus* with *Strongylocentrotus franciscanus*, and observed that the characters of the hybrid larva were the combinations of the larval characters of the parents: for instance, the club-shaped body was that of *purpuratus*, while the round body was characteristic of the *franciscanus* larva. The authors disagree with Tennent's view on the influence of the alkalinity of sea water on the features of the hybrid larva.

Loeb (1910) obtained, in his experiment with *Strongylocentrotus purpuratus* ♀ × *Strongylocentrotus franciscanus* ♂, patroclinous hybrids in respect to several characters. Some larvae showed an abnormality similar to the one obtained by treating the eggs with NaCN. He admitted that the genetical infuence of the sperm appears in the features of the hybrid larva when the sperm nucleus is of the same chemical nature as the egg nucleus, but that otherwise the sperm has no effect.

MacBride (1911–'12) experimented with the cross *Echinus* ♀ × *Echinocardium* ♂ and obtained purely matroclinous hybrids. The reciprocal cross, however, gave matroclinous larvae possessing the aboral spike peculiar to the mother species; the others were patroclinous without any spike. This result was confirmed later by Fuchs (1913).

Doncaster and Gray (1913) crossed *Echinus miliaris* ♀ with *Echinus esculentus* ♂ and got purely matroclinous hybrids from the fertilized eggs from which several chromosomes were eliminated. In the reciprocal cross of the above, however, no elimination of chromosomes occurred; still the hybrid was similarly matroclinous. Based on these observations the authors expressed the view that there is no relation whatever between the characters of hybrids and chromosome elimination.

Shearer, De Morgan and Fuchs (1911–'12) worked on the hybridization of *Echinus miliaris*, *Echinus esculentus* and *Echinus acutus*, taking the presence and absence of the posterior epaulet and of the green pigment as the distinctive features of the hybrid larva. They got matroclinous hybrids from the combination, *Echinus esculentus* ♀ × *Echinus miliaris* ♂, in their experiments during the first two years. In the experiments during the following years on *Echinus miliaris* ♀ × *Echinus acutus* ♂ and on *Echinus miliaris* ♀ × *Echinus esculentus* ♂, however, they got patroclinous larvae. Moreover, in the cross, *Echinus acutus* ♀ × *Echinus miliaris* ♂, matroclinous hybrids were obtained.

Debaisieux (1912) experimented on *Echinus miliaris*, *Echinus esculentus* and *Echinus acutus*, by using the posterior epaulet, posterior pedicellaria and the green pigment as distinctive features. He found that the posterior epaulet was invariably formed and the posterior pedicellaria in most cases, irrespective of the combination of the parents, but that the green pigment never appeared. Moreover, he discovered that no pigment was formed even in the pure bred larvae, when they were kept in starvation.

Hinderer (1914) treated the eggs of *Sphaerechinus* with carbonic acid gas in order to enlarge the nuclei and then fertilized them with the sperm of *Strongylocentrotus*. Thus he obtained more matroclinous hybrids than those developed from untreated eggs.

Köhler (1915–'16) crossed *Strongylocentrotus* with *Sphaerechinus* and got intermediate hybrids in various degrees. He declared that the activity of genes depends not on the alkalinity, salinity or oxygen content of the water, but on the maturity of the germ cells.

Lillie (1921), in his hybridization of *Paracentrotus purpuratus* and *Paracentrotus franciscanus*, found that the *purpuratus* sperm 500 times the ordinary density were required to fertilize the *franciscanus* eggs as compared with the case of straight fertilization of the latter species, while the *franciscanus* sperm 750 times the ordinary density were necessary to fertilize *purpuratus* eggs, as compared with the straight fertilization of the latter species.

Landauer (1922), after treating the *Sphaerechinus* eggs with ammonium solution to expand the nuclei, fertilized them with the *Strongylocentrotus* sperm. Thus he obtained strongly matroclinous hybrid larvae, while the larvae of an intermediate form developed from the control eggs.

Von Ubisch (1923, '31, '32, '33, '33) obtained from crossing experiments with *Echinocardium*, *Echinus*, *Paracentrotus* and *Sphaerechinus*, only matroclinous hybrids, regardless of chromosome elimination occurred or not. The hybrid larvae were of various types, patroclinous, intermediate or matroclinous, according to the season from summer to autumn in which the experiments were carried out. The hybrids were generally matroclinous in the cross *Echinocardium* ♀ × *Ophiothrix* ♂, but the plasms of certain cells were opaque, which is a patroclinous character. Besides, he transplanted the skeleton-forming micromeres of a blastula into another. In the case of homeoplastic transplantations, 75% of the larvae developed normal skeletons, while the rest were abnormal. Nearly the same percentage of successful cases were obtained with *Strongylocentrotus* and *Echinus*, belonging to the same family. The percentage decreased to 69% in the combination of *Sphaerechinus* and *Echinus*, belonging to different families, and to 42% in the combination of *Echinocardium* and *Echinus*, belonging to different orders; in the last case the remaining 58% became chimaerae as far as the skeletal structures were concerned.

Matsui (1924) in his experiment on *Echinarachnius parma* ♀ × *Arbacia punctulata* ♂ got matroclinous hybrids and concluded that the eliminated chromosomes were paternal.

Nümann (1932) demonstrated that the higher the temperature, the more complicated became the larval skeleton. The cross, *Echinocardium cordatum* ♀ × *Echinus miliaris* ♂, yielded hybrids, both intermediate and matroclinous. This fact he ascribes to the difference in the maturity of germ cells. Moreover, he got two types of chimaerae with respect to the skeletal structure, one a mosaic of the parental characters and the other an intermediate between them, by transplanting the skeletal-forming micromeres of both *Echinocardium* and *Echinocyamus* into the whole blastula of *Echinus miliaris* and *Echinus microtuberculatus*.

Moore (1933) carried out crossing experiments with *Dendraster* and *Paracentrotus*, which have highly different cleavage tempos. He found that the cleavage tempo of the hybrid egg is exactly the same as that of the mother species.

Altrogge (1935) transplanted four micromeres of the hybrid from *Echinocardium cordatum* ♀ × *Paracentrotus microtuberculatus* ♂ into the blastula of *Echinocardium cordatum* from which two, three or all the four micromeres had been removed. Thus he obtained chimaerae which showed more paternal influence in proportion to the amount of chromatin contained in the removed micromeres. The reciprocal combination yielded much similar results.

Hörstadius (1936, '40) found, in *Psammechinus miliaris* ♀ × *Echinus esculentus* ♂, that the combination of the green pigment, posterior epaulet and the posterior pedicellaria in the hybrid was different from that in the case of Shearer, De Morgan and Fuchs (1911–'12). Moreover, he succeeded in getting plutei in hybrid merogonies of both directions by using *Psammechinus lividus* and *Paracentrotus microtuberculatus* as material. Thus he confirmed that the merogony hybrid, *Paracentrotus*-cytoplasm + *Psammechinus*-nucleus, was entirely of the *Psammechinus* type. The specific characters in this case, therefore, were determined solely by the nucleus, whereas the larva with the *Psammechinus*-cytoplasm + *Paracentrotus*-nucleus presented the characteristics of *Psammechinus* in some parts of the body.

When we review the works of the previous authors mentioned above, it becomes evident that on the technical side of this kind of experiment, the workers were mainly interested in the questions of whether the cross among different species, genera, families or orders of the echinoids is feasible (or not); whether it can be done with facility or only with some difficulty; whether the hybrid larvae are normal or abnormal; or whether the hybrid presents patroclinous or matroclinous features. On the theoretical side, on the other hand, the points on which many of the workers have been most interested are, whether the various characters of the hybrid larva become patroclinous, matroclinous, mosaic or intermediates of those of the parent species, and how the tendencies appear in each case The question, needless to say, has a direct bearing on the important problem of the relative role played by the chromatin and plasm for the establishment of the larval characters. So far these questions have not yet been answered conclusively. The present investigation was undertaken in the hope of contributing something to the solution of these important problems.

Before going further, I wish to express my hearty thanks to Professor Taku Komai of the Kyoto Imperial University for his kind encouragement and helpful suggestions throughout the course of this work. I am also indebted to the Department of Education, and to the Japan Society for the Promotion of Scientific Research, for their financial aid.

Material and Method

Ten species of echini representing nine genera, six families and two orders were used for this study. Altogether 23 crosses were carried out.

In order to get good results in cross fertilization, only the ripest germ cells were used, and a higher density of sperm-suspension than in the straight fertilization was found necessary.

Bouin's fluid or aceto-sublimate was used as the fixatives, and Heidenhain's haematoxylin as the staining dye. The sections were cut at 5–7 micra in thickness.

In order to exclude the so-called pseudohybrids, the nuclei of the larva were measured and the number of the chromosomes counted. The entire work was carried out during the years 1932–'38 at Katuura in the Prov. of Kii and Goza in the Prov. of Sima.

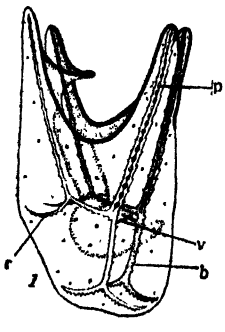
Experiments

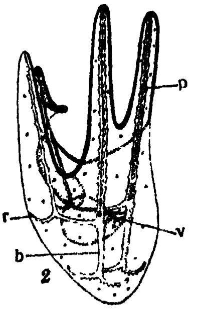
1) *Temnopleurus toreumaticus* ♀ × *Mespilia globulus* ♂

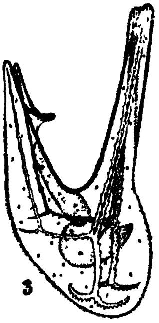
The *Temnopleurus* egg is very small and transparent. The skeleton of the larva (Fig. 1) is of a non-basket structure, with simple recurrent rods (r), a fenestrated postoral rod (p) and mutually intersected ventral transverse rods (v). The body rods (b) are relatively long, and the body is more or less truncated at the posterior end.

The *Mespilia* egg is also very transparent but somewhat larger than the former. The skeletal structure of the larva is similar to that of the *Temnopleurus* larva but different in the body rods (b) which are somewhat shorter, and in the posterior end of the larval body, which is more sharply truncated (Fig. 2).

The cross-fertilization between the two species is as easy as the straight fertilization. The hybrid larvae are normal in appearance (Fig. 3). Most of them have short body-rods and sharply truncated posterior ends. Thus they are largely patroclinous. Some larvae showed abnormalities in their skeletal structures.







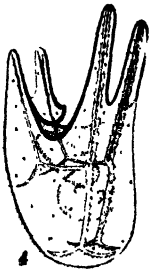
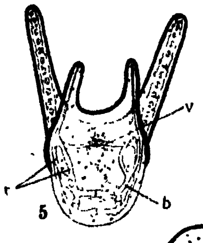
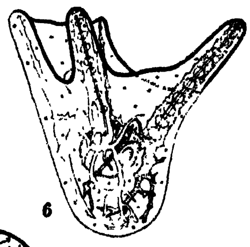


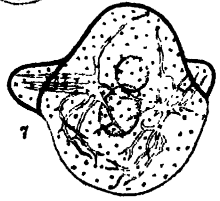
Fig. 1. *Temnopleurus toreumaticus*
Fig. 2. *Mespilia globulus*
Fig. 3. *Temnopleurus toreumaticus* ♀ × *Mespilia globulus* ♂
Fig. 4. *Mespilia globulus* ♀ × *Temnopleurus toreumaticus* ♂

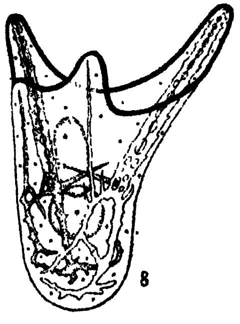
2) *Mespilia globulus* ♀ × *Temnopleurus toreumaticus* ♂

The reciprocal cross of the above also produced normal larvae (Fig. 4). This cross was carried out in two successive summers (1935, 1936); the results obtained were somewhat different. In the first summer both the skeletons and body forms of a greater part of the larvae were patroclinous, but in the second both patroclinous and matroclinous larvae were raised even in the same culture-bowl. No elimination of chromosomes occurred either in the first cleavage or in the division in the later-stage embryos.









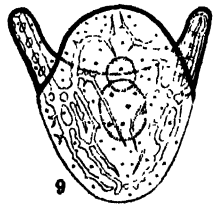


Fig. 5. *Heliocidaris crassispina*
Fig. 6. *Temmopleurus toreumaticus* ♀ × *Heliocidaris crassispina* ♂
Fig. 7. *Temnopleurus toreumaticus* ♀ × *Heliocidaris crassispina* ♂
Fig. 8. *Heliocidaris crassispina* ♀ × *Temnopleurus toreumaticus* ♂
Fig. 9. *Mespilia globulus* ♀ × *Heliocidaris crassispina* ♂

3) *Temnopleurus toreumaticus* ♀ × *Heliocidaris crassispina* ♂

These two species belong to different families. In the latter species the egg is small and very opaque; the larval skeleton is of a compound-basket structure with double recurrent rods (r), united ventral transverse rods (v) and short body rods (b) (Fig. 5), thus differing considerably from that in the former species; the body is truncated at the posterior end. Only a few eggs developed from this cross. The larvae had very irregular skeletons, so that it was very hard to decide the genetic affinity of the hybrid (Fig. 6). No elimination of chromosomes, however, occurred in the cell divisions examined. Some larvae had a great quantity of pigment (Fig. 7). The larvae died within a few days.

4) *Heliocidaris crassispina* ♀ × *Temnopleurus toreumaticus* ♂

In this cross which is reciprocal of the above, only a few eggs developed. The hybrid larvae were abnormal (Fig. 8). Chromosome elimination occurred in the first cleavage. This fact may deserve special mention as a contrast to the preceding case.

5) *Mespilia globulus* ♀ × *Heliocidaris crassispina* ♂

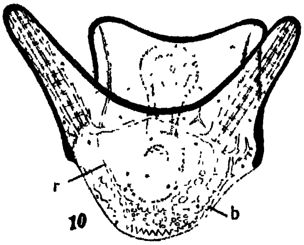
In this cross still fewer eggs developed. The larvae were extremely abnormal (Fig. 9), and some were strongly pigmented. Chromosome elimination was not found either in the first cleavage or in the subsequent cell divisions.

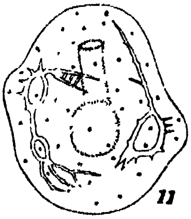
6) *Temnopleurus toreumaticus* ♀ × *Astriclypeus manni* ♂

Very few eggs developed in this interordinal crossing. The skeleton of of the *Astriclypeus* larva is of a simple-basket structure (Fig. 10), and the body (b) and recurrent rods (r) form an intricately fenestrated plate at the posterior end. The hybrid larvae were very abnormal, as expected (Fig. 11); but no chromosome elimination occurred, a fact worthy of special notice.

7) *Heliocidaris crassispina* ♀ × *Toxopneustes pileolus* ♂

In this interfamilial cross many eggs were fertilized. The skeleton of the *Toxopneustes* larva is of a simple-basket structure (Fig. 12) with a simple recurrent rod (r) and long body rods (b), the ventral transverse rods (v) coming in slight contact with each other. The body is rounded at the posterior end. The development of the *Heliocidaris* larvae is more rapid than that of *Toxopneustes*. The developmental rate of the hybrid larvae was intermediate between these of the





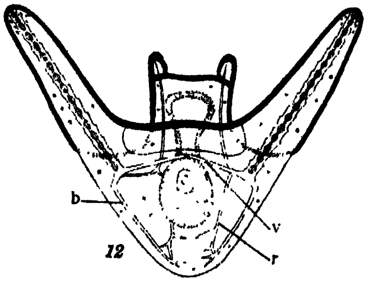


Fig. 10. *Astriclypeus manni*
Fig. 11. *Temnopleurus toreumaticus* ♀ × *Astriclypeus manni* ♂
Fig. 12. *Toxopneustes pileolus*

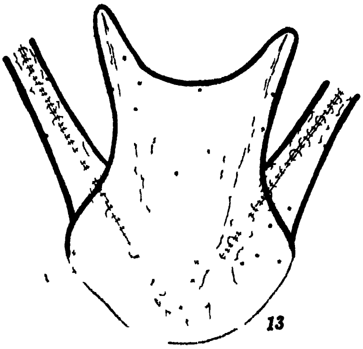
parent species. Almost all of the hybrid larvae were strongly matroclinous, possessing the compound-basket structure and the united ventral transverse rods (v) (Fig. 13).

8) *Toxopneustes pileolus* ♀ × *Heliocidaris crassispina* ♂

The egg of *Toxopneustes* is transparent and larger than any of the eggs of the forms employed in this study. In this cross which is reciprocal of the above, a few eggs developed into highly abnormal plutei.

9) *Echinometra Mathaei* ♀ × *Heliocidaris crassispina* ♂

The egg of *Echinometra* is as small and opaque as that of *Heliocidaris.* The skeleton of the larva (Fig. 11) is of a compound-basket structure such as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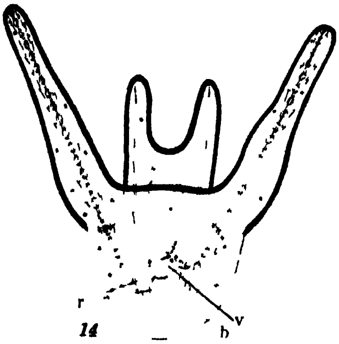
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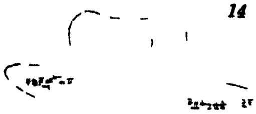
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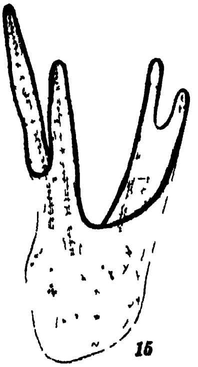
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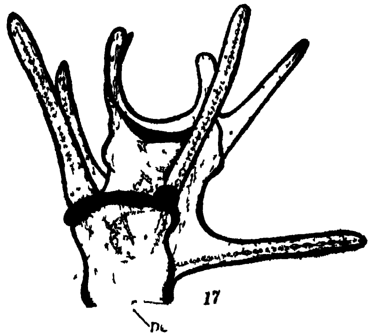
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Fig. 13. *Heliocidaris crassispina* ♀ × *Toxopneustes pileolus* ♂
Fig. 14. *Echinometra Mathaei*
Fig 15 *Echinometra Mathaei* ♀ × *Heliocidaris crassispina* ♂
Fig. 16. *Heliocidaris crassispina* ♀ × *Echinometra Mathaei* ♂
Fig. 17 *Echinometra Mathaei* ♀ × *Toxopneustes pileolus* ♂

that of the *Heliocidaris* larva, possessing double recurrent rods (r), united ventral transverse rods (v), and short body rods (b). The cross-fertilization was as easy as the straight fertilization. The hybrid larvae were strongly matroclinous (Fig. 15), but some larvae were extremely abnormal in their skeletal structures.

10) *Heliocidaris crassispina* ♀ × *Echinometra Mathaei* ♂

This cross, reciprocal of the above, yielded extremely abnormal hybrid larvae (Fig. 16) which soon died. This seems noteworthy as a contrast to the former cross.

11) *Echinometra Mathaei* ♀ × *Toxopneustes pileolus* ♂

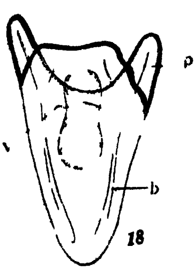
A large amount of eggs were fertilized and developed. Almost all of the hybrid larvae were strongly matroclinous (Fig. 17). The development was so acceralated that pedicellariae (pe) were formed sooner than in the pure bred larvae; some larvae reached the metamorphosing stage, but others were extremely abnormal and died earlier. It is rather remarkable that this interfamiliar crossing was so successful.

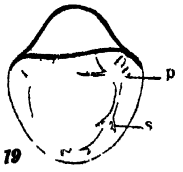
12) *Toxopneustes pileolus* ♀ × *Echinometra Mathaei* ♂

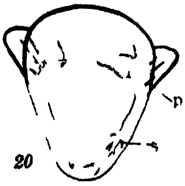
In this cross, reciprocal of the above, about 10% of the eggs developed to the blastula stage.

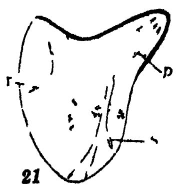
13) *Strongylocentrotus pulcherrimus* ♀ × *Heliocidaris crassispina* ♂

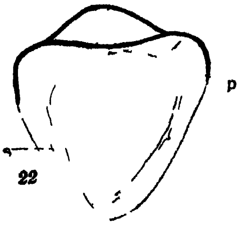
The egg of *Strongylocentrotus* is rather opaque. The skeleton of the larva is of a non-basket structure (Fig. 18) with simple postoral (p), separate, ventral, transverse (v), and short body rods (b), but without any recurrent rods. The body is truncated sharply at the posterior end. The postoral rod (p) of the *Heliocidaris* larva is of the fenestrated type consisting of three longitudinal bars connected by many cross-bars, while that of the *Strongylocentrotus* larva is simple. This clear distinction makes the cross highly suitable for such a study. The cross-fertilization was so successful that many eggs developed to the pluteus stage. The postoral rod (p) of the hydrid larva, as seen in Figs. 19, 20, 21, is neither of the simple nor of the fenestrated type, but consists of three or four parallel rods. Such a feature of the hybrid has been regarded by certain previous authors as intermediate, and is con-











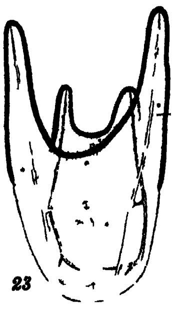


Fig 18 *Strongylocentrotus pulcherrimus*

Fig 19–21 *Strongylocentrotus pulcherrimus* ♀ × *Heliocidaris crassispina* ♂

Fig 22 *Pseudocentrotus depressus* larva reared under abnormally high temperature ca 27°C

Fig 23 *Pseudocentrotus depressus*, normal larva

sidered to have developed under paternal influence. I am rather inclined to regard this as a pathological feature, for I have raised larvae (Fig. 22) of *Pseudocentrotus depressus* having the postoral rod (p) consisting of three, sometimes four, parallel bars by keeping the developing eggs at 27°C, when the sea water temperature was 10°C. The normal larva (Fig. 23) of this species has a simple postoral rod (p). The postoral rods of these heated larvae showed no difference from those of the hybrid larva mentioned above. Furthermore, both the larvae have an extraordinarily large spicule on the body rod, which is evidently another pathological feature because such a spicule never appears in the normal larva. Thus, one must be on his guard in judging whether the skeletal type of the larva is paternal, maternal or intermediate.

Even in the case where the parallel rods were less than three we could not have decided whether or not it was a hybrid feature, whereas if the rods are more than three it is clear that this feature is not the product of the hereditary influence from the parents, for the rods in a normal larva is never more than three.

It is clear then that the abnormal postoral rods appearing in the hybrid and heated larvae are both pathological products brought about, one by cross incompatibility, and the other by high temperature.

Thus, the postoral rod in such cases is unsuitable for the decision of characters, and some other stable structure must be chosen. The cytoplasm of the hybrid larvae stained dark green, like that of the paternal species. In the early stage the hybrid larvae were roughly matroclinous, but they showed a patroclinous character by having the recurrent rod (r).

14) *Heliocidaris crassispina* ♀ × *Strongylocentrotus pulcherrimus* ♂

In this cross, reciprocal of the former, a fairly large quantity of eggs developed, but their development stopped in the cleavage stage.

15) *Strongylocentrotus pulcherrimus* ♀ × *Toxopneustes pileolus* ♂

A pretty large amount of eggs developed in this hybridization, but the observation could not be continued as I was obliged to leave the laboratory for other duties.

16) *Echinometra Mathaei* ♀ × *Parasalenia gratiosa* ♂

The eggs of *Parasalenia* are somewhat opaque and rather large. The larval skeleton is of a compound-basket structure, with double recurrent rods (r) and a disproportionately long postoral rod (p), except in the early stage (Fig. 24). The ventral transverse rods are connected with each other; the body rod has conspicuous spines at the posterior end. The body is truncated. Judging from the structure of the adult and from the larval skeleton, *Parasalenia* is no doubt akin to *Echinometra*. The cross between them, however, has yielded no satisfactory results in spite of repeated trials. This shows that systematic kinship does not always ensure the success of crossing.

17) *Parasalenia gratiosa* ♀ × *Echinometra Mathaei* ♂

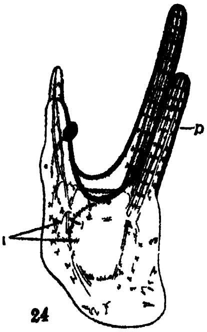
No fertilization took place in the cross reciprocal of the above.

18) *Temnopleurus toreumaticus* ♀ × *Parasalenia gratiosa* ♂

This is a distant cross between different families. Yet a lot of eggs developed, contrary to expectations — a fact of some interest in contrast to the two preceding cases. The hybrid larvae (Fig. 25) were almost purely matroclinous, though no chromosome elimination could be noticed in the first cleavage. The average diameter of the mesenchyme cell nuclei of the hybrid was 1.4 mm, while that of *Temnopleurus* was 1.3 mm, and that of *Parasalenia* 1.7 mm; the hybrids may be said to be matroclinous in this respect.

19) *Parasalenia gratiosa* ♀ × *Temnopleurus toreumaticus* ♂

In this cross which is reciprocal of the above, a few eggs developed, contrary to the former case. The hybrid larvae were roughly matroclinous (Fig. 26), but they displayed a patroclinous character in their simple recurrent rods (r).



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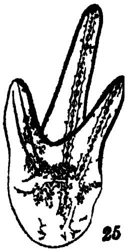

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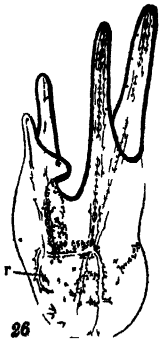

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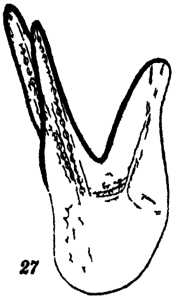
Fig 24 *Parasalenia gratiosa*

Fig 25 *Temnopleurus toreumaticus* ♀ × *Parasalenia gratiosa* ♂

Fig 26 *Parasalenia gratiosa* ♀ × *Temnopleurus toreumaticus* ♂



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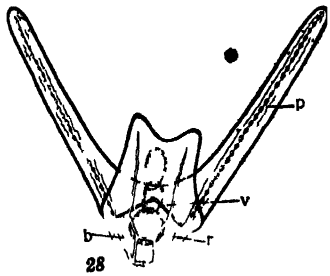

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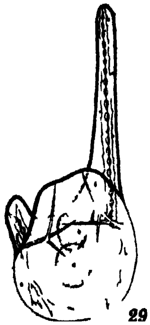

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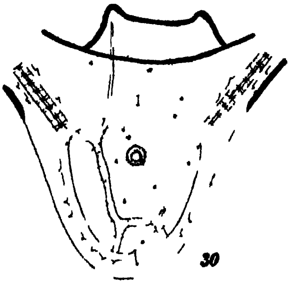

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Fig 27 *Mespilia globulus* ♀ × *Parasalenia gratiosa* ♂

Fig 28 *Diadema setosum*

Fig 29 *Mespilia globulus* ♀ × *Diadema setosum* ♂

Fig 30 *Parasalenia gratiosa* ♀ × *Toxopneustes pileolus* ♂

20) *Mespilia globulus* ♀ × *Parasalenia gratiosa* ♂

A small amount of the eggs developed; the hybrid larvae (Fig. 27) were generally matroclinous.

21) *Parasalenia gratiosa* ♀ × *Mespilia globulus* ♂

In this reciprocal cross of the former, no fertilization occurred.

22) *Mespilia globulus* ♀ × *Diadema setosum* ♂

These species belong to different families. The skeleton of the *Diadema* larva is of a simple basket structure, with a simple recurrent rod (r), united ventral transverse rods (v), fenestrated postoral rod (p), and short body rods (b) (Fig. 28). The body is truncated at the posterior end.

A very few eggs developed from the cross, and these became matroclinous hybrid larvae (Fig. 29).

23) *Parasalenia gratiosa* ♀ × *Toxopneustes pileolus* ♂

A very few eggs developed from this cross. The single larva observed showed patroclinous features, though it was defective in a part of the skeleton (Fig. 30).

Discussion

It is known that the sea-urchin eggs can develop without the entrance of the sperm if they are treated with butylic acid or other chemicals (artificial parthenogenesis). The development also may occur even in the case where the sperm remains in the egg cytoplasm without fusing with the egg nucleus (gynogenesis). In still other cases even an egg-fragment containing no nuclear substance can develop when penetrated by a sperm (merogony or androgenesis). These facts must be taken into consideration in the interpretation of the results obtained in hybrizatlon experiments. Another point which should be particularly noted is that the hybrid characters appearing in the early stage of development may be mostly, if not entirely, under the influence of the maternal hereditary materials. Moreover, there must be characters that are fixed by the activity of a number of genes, dominant or recessive in various degrees. That the larval skeletal type is strongly affected by the environmental conditions, such as temperature and chemical composition of sea water, also should not be overlooked. Thus, it is often very difficult to find the right interpretation of a given feature of the hybrid larva.

I) *On the success or failure, difficulty or facility of hybridization*

The success or failure of a cross fertilization depends primarily on the systematic affinity of the parent species. This, however, is not always the case as was clearly demonstrated by some of the above experiments as well as by the works of Elsters (1935) and others. This seems to be due to the fact that in hybridization a cortical reaction, different from that in the straight fertilization, appears on the penetration of foreign sperm, as pointed out by P. Hertwig (1936). Thus, a combination of which the fertillization is commonly regarded as impossible can often be made a feasible one merely by raising the concentration of the sperm (Lillie, 1921), by exposing the fresh eggs in normal sea water for some hours (O. and R. Hertwig, 1887), or by treating the eggs with some chemicals (Loeb, 1903–'4; Tennent, 1924). The success or failure of crossing therefore seems to depend more on the mechanical or chemical state of the germ cells concerned than on the genetical affinity of the parents. This assumption is supported by the fact that the results of the reciprocal crosses are often different: for instance the cross

Toxopneustes ♀ × *Heliocidaris* ♂ or *Echinometra* ♂ gives only a very poor result, whereas the reciprocal cross yields a very fruitful result. This difference is probably to be attributed by the size of the *Toxopneustes* egg and sperm which are much larger than those of the other species. The small sperm of *Heliocidaris* or *Echinometra* are therefore incapable of penetrating *Toxopneustes'* large egg, while the latter's large sperm can easily penetrate the small egg of the former species and activate its development. Newman (1923) also expressed a nearly identical opinion in the crossing of *Strongylocentrotus purpuratus* × *Strongylocentrotus franciscanus*. The same is apparently true of the fact that crossing is possible between *Temnopleurus toreumaticus* and *Parasalenia gratiosa* belonging to different families, whereas it is impossible between *Echinometra Mathaei* and *Parasalenia gratiosa* of the same family.

II) *Eliminatian of Chromosomes*

It is generally known that when the eggs of echinoids are fertilized by the sperm of another echinoid species or of a mollusc, annelid or crinoid (Kupelwieser, 1906–'12; Godlewski, 1906; Baltzer, 1910; Tennent, 1912; Doncaster and Gray, 1913; von Ubisch, 1923; Matsui, 1921; P. Hertwig, 1936), the elimination of chromosomes often takes place. The eliminated chromosomes are considered to be mostly those from the sperm, but may be those from the egg. It is assumed, furthermore, that some particular chromosomes are more liable to be eliminated than others. The elimination may occur in any stage, from the first cleavage to blastula.

There is a great variety of opinion among previous authors as regards this phenomenon. According to Tennent (1912), there is a definite correlation between the eliminated chromosomes and the larval characters. But there is scarcely any experimental result supporting this view. When the sperm of a mollusc, annelid or a crinoid, is employed to fertilize an echinoid's egg, elimination of chromosomes usually occurs, and the larval characters invariably present a strongly matroclinous tendency even when the development is normal. In such cases the eliminated chromosomes are paternal without doubt, and the development must be taken as gynogenesis.

In the crosses among echinoids, on the other hand, the chromosome elimination does not necessarily occur even in the case of a distant cross, as shown in the above experiment with *Temnopleurus* × *Astriclypeus*, and also in von Ubisch's (1923) experiment of crossing *Echinocardium* with *Echinus*. The reciprocal crosses often give different results in this respect, as shown in the author's cross between *Temnopleurus* and *Echinus*, as well as in Tennent's (1912) cross between *Toxopneustes* and *Hipponoë*. Thus, the elimination of chromosomes does not seem to have any direct bearing on the abnormality of the hybrid larva. The elimination is probably no more than a sign of adjustment to the abnormal combination of nuclear substance and cytoplasm. The same adjustment might be accomplished simply by making the paternal nucleus inert, without eliminating it, as indicated by the above experiment on *Temnopleurus* × *Parasalenia* and also by Godlewski's experiment (1906). At any rate, it is too much to consider the elimination to be the cause of the abnormality of the hybrid larvae.

III) *Matroclinous vs. Patroclinous tendency of the hybrid*

In hybridization the paternal genes do not as a rule affect the larval characters that appear in the early stage of development. For instance the cleavage tempo, according to Moore (1933), is exactly like that of the maternal species. Some authors, however, do not agree with this view and hold that the tempo becomes slower than that of either parent species (Seeliger, 1895; Fischel, 1906; von Ubisch, 1923; Nümann, 1933), or that it becomes faster (Tennent, 1912). In my experiment on *Heliocidaris* ♀ × *Toxopneustes* ♂, the hybrid developed quicker than the larva of either species, the development rate of the *Toxopneustes* larva being the slowest. The retardation in the former case was probably due to the pathological state of the hybrid, while the acceleration in the latter case was possibly a sign of heterosis.

As for the size of blastomeres, the hybrid is said generally to approach that of the maternal species (Boveri, 1903–'4; Driesch, 1903; Fischel, 1906). The segmentation of the blastomeres, on the other hand, is considered to be affected by paternal genes (Fischel, 1906; von Ubisch, 1923). I have observed that the cytoplasm of the hybrid larvae obtained from the cross, *Strongylocentrotus* and *Heliocidaris*, becomes conspicuously dark green, which is a paternal character. This case deserves special notice on account of the appearance of the paternal influence at a very early stage.

Next, the skeletal type of the hybrid larva usually becomes intermediate between, or a mixture of, the parental types. This is presumably due to the fact that the skeletal structure is determined by many genes. Among these there may be dominant, incomplely dominant and recessive genes, and these genes will be different according to species, local race and individual. Besides, the skeletal structure is rather strongly influenced by environmental factors (Loeb's experiment). Under the influences of these genetical and environmental factors in various combinations, the skeletal type of each larva will be established. Thus, it is no wonder that experiments on the same material carried out on different occasions sometimes yield different results. In most cases, however, the hybrid larva strongly tends to resemble the maternal race rather than the paternal. This tendency is more apparent in distant crosses, evidently because such a cross often becomes essentially identical with parthenogenesis or gynogenesis. Even in the cross between allied species the tendency to become matroclinous appears more frequently than the leaning toward the patroclinous. In such cases too, the development is probably essentially gynogenetic or parthenogenetic. There must also be cases where the skeletal type is predetermined and impressed upon the cytoplasm mainly the maternal genes before fertilization. This view is supported by Driesch's observation (1906) that the number of the primary mesenchyme cells -- the primordia of the skeleton — of the hybrid gastrula is identical with that of the mother species.

Besides, there are some workers who believe that the tendency of the hybrid larva to become patroclinous or matroclinous is determined by the relative maturity of the germ cells (Vernon, 1899; Köhler, 1915–'16). Köhler

(1915) maintains that when over-mature eggs are fertilized by sperm of low maturity, more matroclinous larvae are obtained than in the case where the eggs of low maturity are fertilized by over-mature sperm. This is probably due to the fact that more genetic influences of the mother becomes impressed upon the cytoplasm with the maturity of the egg. The maturity of the sperm is probably not so important as that of the egg for the appearance of the characters in the hybrid larvae. This, however, should be confirmed by future experiments.

Certain authors hold the view that the matroclinous tendency is increased in proportion to the degree in which the temperature is raised (Doncaster, 1904; Herbst, 1906), although the experimental evidence is far from conclusive. If this is true, it is probably because the high temperature raises the metabolic activity of the egg, thus causing the maternal characters to become more strongly impressed upon the cytoplasm than otherwise. The same tendency seems to appear when the egg-nucleus is enlarged artificially (Hinderer, 1914; Landauer, 1922). By this means the activity of the genes in the egg-nucleus is apparently increased.

As for the variability of results obtained by different workers, or even by the same worker on different occasions with the same material, it may be due to the influence of some environmental factor, such as temperature, or to the difference in the genetic constitutions of the material. The latter seems to be especially plausible, when the results of the experiments carried out at different localities differ.

The patroclinous characters appearing in the hybrid are probably due to dominant genes in the sperm. But there seems to be cases in which the abnormality of the offspring happens to coincide with that of the character in the father. This possibility has been pointed out by Hörstadius (1940) also.

The other characters appearing after the larval skeleton, such as the posterior epaulets, posterior pedicellariae, and the green pigment formed in a later stage, are probably determined on the Mendelian basis (Debaisieux, 1912). These characters, however, are highly variable. For instance, Shearer, De Morgan and Fuchs (1912) obtained entirely different results in their experiments of crossing *Echinus miliaris* ♀ × *Echinus esculentus* ♂, one of which was carried out in 1909–1911 and the other in 1912. In the earlier experiment the hybrid larva showed a matroclinous tendency in having the green pigment and no posterior ciliated epaulet, while in the later experiment the larva presented a patroclinous tendency in having the posterior cilliated epaulet and no green pigment. Hörstadius (1940) when worked on the same material, got a result different from either of the ones mentioned above; he obtained hybrid larvae having neither green pigment nor posterior epaulet. This is a good illustration of the great variability of the results in hybridization experiments. The larval characters, even those appearing in late stages presumably under genetic influence, may vary according to the material used in different years or according to environmental conditions.

IV) *The affinity of the parents as a factor for the success of hybridization*

It is clear that there exists a limit in the compatibility of the egg-plasm and the foreign sperm. This is well established by the experiments of merogony which greatly depends on the affinity of the parent species; the development takes place only when the sperm is from a species allied to that of the egg piece (Hörstadius, 1936). The compatibility among the chromosomes or genes of the parent species is another controlling factor. There are undoubtedly cases where development stops at an early stage, owing to heteroploidy or other genetical unbalance.

It is interesting that the result of the cross between parents whose larval skeletal types resemble each other is generally successful even if the skeletal types of the adults show a fairly large difference, as shown by the crosses between *Temnopleurus* and *Mespilia*, and that between *Echinometra* and *Heliocidaris*. This is probably due to that, because of the resemblance of the reactive patterns of the larval development, the disturbance in the development of the skeleton of the hybrid larva is comparatively small. Thus, it is clear that the compatibility in this case mainly concerns the type of the larval skeleton.

Summary

(1) The echinoids employed in the present experiments represent ten species, nine genera, six families and two orders: namely, *Temnopleurus toreumaticus*, *Mespilia globulus*, *Strongylocentrotus pulcherrimus*, *Heliocidaris crassispina*, *Echinometra Mathaei*, *Parasalenia gratiosa*, *Diadema setosum*, *Toxopneustes pileolus*, *Pseudocentrotus depressus* and *Astriclypeus manni*. Interspecific, intergeneric and interordinal crosses were carried out.

(2) The success or failure, and the difficulty or facility of the cross primarily depend on the systematic relationship of the materials. There are cases, however, where a distant cross is easier than the cross between related species. For instance, whereas the cross between *Echinometra* and *Parasalenia*, belonging to the same family, is hardly possible, the cross between *Temnopleurus* and *Parasalenia*, belonging to different families, is very easy. This seems to show that hybridization is subject to a condition different from that in straight fertilization; the development in the former case is apparently initiated by purely mechanical or chemical stimulus.

(3) The chromosome elimination frequently occurs in various stages from the first cleavage to the blastula; but there seems to be no general rule as to whether the elimination should occur or not. Besides, elimination is not a necessary condition for the abnormality of the hybrid larva. It is apparently no more than a sign of adjustment to the incompatibility between the chromosomes, or to that between the chromosomes and the cytoplasm. The foreign sperm chromosomes may become inert even when they are not eliminated.

(4) The characters appearing in the early stage of the hybrid larva, for instance, the cleavage tempo and the size of blastomeres, are generally determined by the genetic complex of the mother. Such characters as pigmenta-

tion, however, even though appearing in early stages are influenced by the sperm.

(5) The effect of the sperm is stronger on the characters appearing later in development, for instance the skeletal type of the larva. This character is, however, apparently under the influence of a number of genes. Different species or local races, and even different individuals, may have different complexes with respect to these genes. Furthermore, their phenotypic effects will vary considerably under the influence of environmental factors. All these account for the striking variability of the results obtained on different occasions or by different workers, even if the same species were used as the material.

(6) Roughly speaking, however, the skeletal type of the hybrid is usually matroclinous. This seems to be due to the fact that the skeletal type is largely laid out before fertilization under the influence of the maternal genes.

(7) As regards the observations that the maturity of germ cells and the temperature of sea water are important factors for determining the larval characters, they are probably due to the fact, that if the period before fertilization is long, the egg gets more influence from the maternal genetic complex, and this influence is probably stronger under high temperature.

(8) The "patroclinous" characters may be due to mere coincidence resulting from pathological development caused by abnormal chromosome combinations, or by external factors. For instance, there are cases where the skeletal type of the hybrid larva happens to resemble the paternal type by becoming an abnormally complicated or simplified structure; and such abnormalities may appear either by the effect of high temperature, or by hybridization.

(9) The characters which make their appearance in a still later stage of development, such as epaulet, pedicellaria and pigment, are, as a rule, determined according to the Mendelian law of inheritance, namely, by the interaction of both the maternal and paternal genes. But there are apparently cases where they are determined by the egg genes in an early stage. This accounts for the discrepancy found among the experimental results obtained by previous workers.

(10) The success or failure of hybridization experiments depends largely on the systematic affinity of the parents. But it is noteworthy that the cross between parents, even of very remote kinship, may be successful if the larval skeletal types are alike. This is probably because the development greatly depends on the reaction pattern of the developing larva.

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5. Studies on the Helminth Fauna of Japan
Part 43. Mammalian Nematodes, IV

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RHABDIASIDAE Railliet, 1915

1. *Strongyloides papillosus* (Wedl, 1856) Ransom, 1911

Text-figs. 1-3

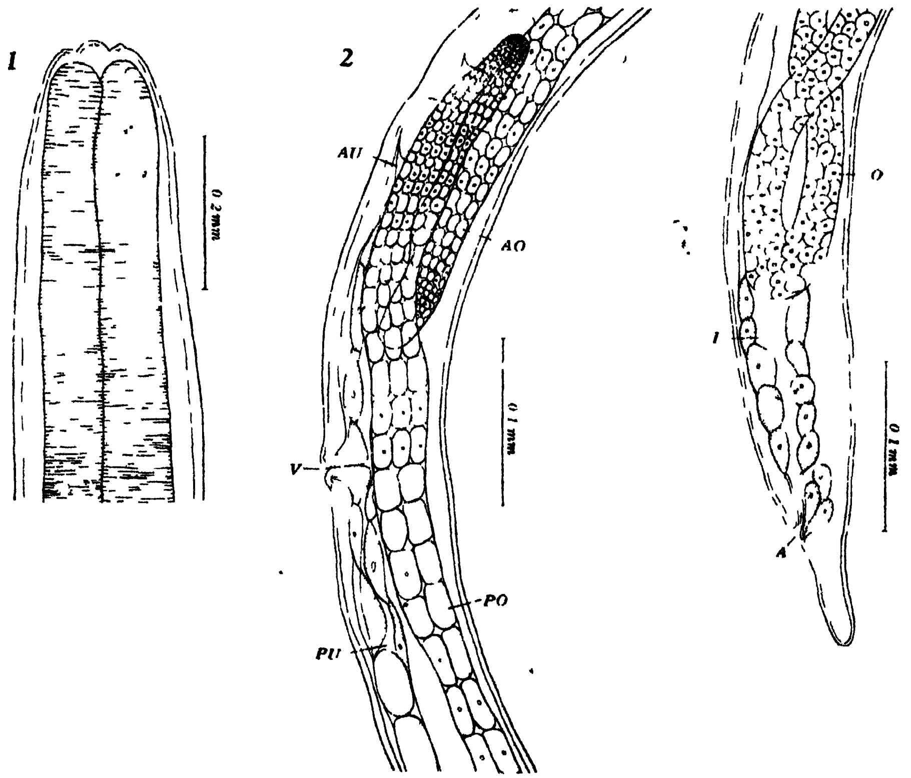
Habitat. Small intestine of *Ovis aries*

The present material comprising 10 parasitic forms shows some differences in measurements from Hall's.

	Hall	Present author
Body	3.5 6.0×0.05–0.06	4.2-6.0×0.05–0.07
Esophagus	0.65-0.8	0.82–0.97
Tail	55–70 μ	50-70 μ
Vulva from tail end	1.6 2.0	1.5 2.5
Eggs	40-60×20-25 μ	48 60×22-23 μ

LITERATURE

Hall, M. K. Nematode parasites of mammals of the orders Rodentia, Lagomorpha, and Hyracoidea Proc. U. S. Nat. Mus., 50, 1916, 6 7.



Figs. 1–3. Parasitic form of *Strongyloides papillosus* (Wedl, 1856).
Fig. 1. Anterior extremity, lateral view.
Fig. 2. Vulvar region, lateral view.
Fig. 3. Posterior extremity, lateral view.

TRICHURIDAE Railliet, 1915

2. *Trichuris ovis* (Abildg., 1795) Smith, 1908

Text-fig. 4.

Habitat. Ceca of *Ovis aries*

MALE. Body 63 × 0.65 mm. Bacillary band originating at about level of nerve ring, 130μ wide at posterior part of esophagus, Vesicular swellings of cuticle in two longitudinal rows, extending for a distance of 1.75 mm from 0.5 mm behind head end. Anterior portion of esophagus 0.83 mm long, posterior portion 41 mm long, entire length about twice the length of intestinal region. Para-esophageal cells about 210 im number. Testis commencing at a point 2.8 mm from tail end, turning backward 0.15 mm behind posterior end of esophagus; vesicula seminalis about 8 mm long by 0.4 mm wide, joining ductus ejaculatorius by a narrow duct about 0.3 mm long. Ductus ejaculatorius 7.7 mm long provided with a very thick wall of circular and longitudinal muscle fibers. Spicule 6.65 mm long, about 0.1 mm in diameter at its basal swelling, finely striated transversely throughout its length, terminating in a sharp point. Spicular sheath 1.5 mm long, telescoped at its distal end, covered all over with minute spines which are 8μ long at the proximal end and gradually diminish in size toward the distal end. Cloacal aperture ventroterminal.

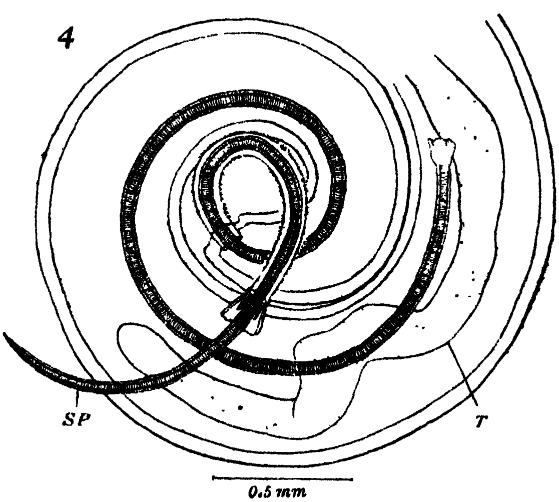


Fig. 4. Posterior extemity of male of *Trichuris ovis* (Abildg., 1795), lateral view.

FEMALE. Body 50–70 × 0.8–0.9 mm. Ratio of two body regions varying from 2.8 : 1 to 3.5 : 1. Ovary originating at posterior end of body, turning back on itself 0.75–1.0 mm behind vulva; vagina winding, strongly muscular, 2.2–3.5 mm long lineally. Vulva a little behind junction of esophagus with intestine, covered with sharp spines up to 10μ long. Anus at blunt-pointed posterior extremity. Eggs 60–81μ long including the polar plugs, 31–34μ broad.

The present material agrees well with Hall's description.

LITERATURE

Hall, M. C. Nematode parasites of mammals of the Orders Rodentia, Lagomorpha and Hyracoidea. Proc. U. S. Nat. Mus., 50, 1916, 28–30.

3. *Capillaria suis* n. sp.

Text-fig. 5.

Habitat. Stomach of *Sus leucomystax leucomystax* Temminck.

Localities. Yamaguti and Wakayama Prefectures.

MALE. Body 13–14.5 × 0.06–0.075 mm. Bacillary band extending from behind nerve ring to posterior extremity, up to 20 μ broad at posterior part, its elements arranged in a single row anteriorly. Nerve ring 70–80 μ from head end. Anterior portion of esophagus 0.42–0.63 mm long, posterior portion 4.8–5.5 mm long, entire length 5.4–5.7 mm. Ratio of esophageal to intestinal portion 1 : 1.3–1.6. Para-esophageal cells 38–48 in number. Spicule 0.78–0.85 mm long, 9 μ broad at anterior end. Spicular sheath 14 μ wide, about 0.2 mm long when everted, finely wrinkled transversely. Caudal bursa delicate, membranous, projecting 15–18 μ further back of caudal end of pulp, supported ventrally by an inner pair of slender digitiform processes and on outer pair of hammer-shaped processes, of the pulp.

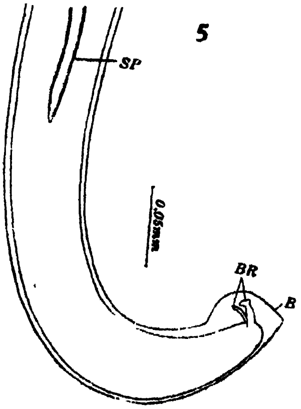


Fig. 5. Posterior extremity of male of *Capillaria suis* n. sp., lateral view.

FEMALE. Body 19–22 × 0.08–0.09 mm. Bacillary band similar in anteroposterior extent to that of male, up to 30 μ broad. Nerve ring 75–90 μ from head end. Anterior portion of esophagus 0.54–0.62 mm long, posterior portion 5.2–5.9 mm long, total length 5.8–6.5 mm. Number of para-esophageal cells within the range given above for the male. Ratio of two body regions 1 : 2.2–2.5. Vulva 0.12–0.15 mm behind esophagus, 5.9–6.6 mm from anterior extremity, without appendages. Posterior extremity rather rounded, with terminal anus. Eggs 57–72 μ in length including polar prolongations, 24–30 μ in breadth, without sculpturings on surface.

The differences between the present species and the most closely related *C. splenacea* (Duj., 1843) Travassos, 1915, are shown in the following table.

	C. Splenacea	*C. suis*
Body length	♂ 11-13 ♀ 24-37	♂ 13-14.5 ♀ 19-22
Length of esophagus	5.0	♂ 5.4-5.7 ♀ 5.8-6.5
Length of spicule	0.88	0.78-0.85
Vulva from head end	5.6	5.9-6.6
Anus	subterminal	terminal

It is to be regretted that the number of the para-esophageal cells has not been counted for any of the described mammalian species except *C. aerophila*, although it constitutes one of the most important specific characters.

LITERATURE

Teixeira de Freitas, J. F. and Herman Lent, Estudo sobre os Capillariinae parasitos de mammiferos (Nematoda: Trichuroidea). Men. Inst. Osw. Cruz, 31(1), 1936, 85-160.

STRONGYLIDAE Baird, 1853

4. *Triodontophorus brevicauda* Boulenger, 1916

Text-fig. 6; Pl. XLVII, Figs. 1-3.

Habitat. Colon of Korean pony.

Locality. Quelpart Island (Saisyu-to), Korea.

The following measurements being from contracted examples are somewhat different from those given by the original author.

MALE. Body 10.8–13.1 × 0.75–0.9 mm. Mouth collar 0.2–0.22 mm in diameter, with erect margin. Leaf-crown elements setiform 60–69 in number, projecting very little beyond submedian papillae. Buccal capsule 0.16–0.2 × 0.2–0.23 mm, with 6 petaloid marginal thickenings, each of which is so deeply incised at the middle that it appears distinctly 2-lobed. Buccal tooth with 3 simple points and not denticulated. Nerve ring, excretory pore and cervical papillae removed anteriorly (0.28–0.35 mm, 0.4–0.45 mm and 0.45–0.6 mm respectively from anterior extremity) owing to contraction of the body. Esophagus 1.05–1.2 × 0.2–0.21 mm. Bursa finely striated longitudinally, fringed with minute spiniform projections; dorsal lobe elongated, marked off from lateral lobes, two stems of dorsal ray nearly parallel to each other, each with two outer branches proximally. Length of dorsal ray (from its tip to origin of externodorsal ray) 0.7–0.8 mm.

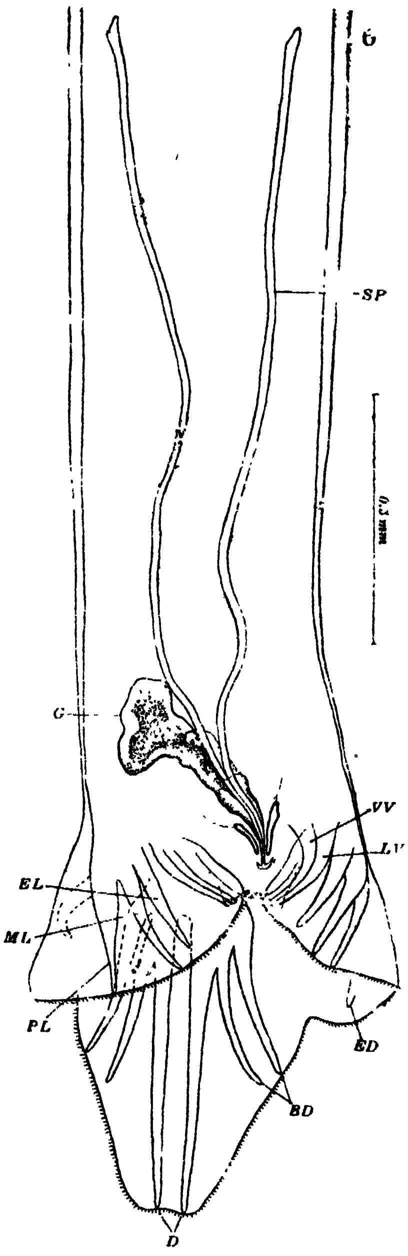


Fig. 6. Posterior extremity of male of *Triodontophorus brevicauda* Boulenger, 1916, ventral view.

Genital cone prominent. Spicules slender, about 1.7 mm long, barbed at their fused tip. Gubernaculum approximately pistol-shaped, 0.4–0.45 mm long, with very large handle, whose greatest diameter is 0.175-0.2 mm.

FEMALE. Body 12–13.5 × 0.8–1.1 mm. Mouth collar with erect margin, 0.21–0.24 mm in diameter. Leaf-crown consisting of 63–70 elements, Buccal capsule 0.2–0.23 × 0.22–0.25 mm. Esophagus 1.15–1.25 × 0.22–0.25 mm. Tail rudimentary, only 70–80 μ long. Vulva 0.17–0.23 mm in front of anus, 0.25–0.33 from tail end. Eggs elliptical, thin-shelled, not yet fully embryonated when deposited, 90–105 × 42-57 μ.

5. *Triodontophorus serratus* Looss, 1900

Text-figs. 7–8; Pl. XLVII, Figs 4–6

Habitat. Caecum of *Equus caballus orientalis*.

Locality. Kodaira near Tokyo.

The following account is based on two mature males and six gravid females fixed in formalin in somewhat contracted state.

MALE. Body 11.8–13.1 × 0.7–0.83 mm. Mouth collar 0.16 mm in diameter. Leaf-crown consisting of 55 elements. Buccal capsule 0.09–0.12 × 0.15-0.16 mm, with dorsal gutter opening at its anterior margin, capsule teeth denticulated along anterior margin closs to outer tips. Esophagus 1.1–1.13 × 0.18–0.23 mm. The nerve ring, excretory pore and cervical papillae are unusually anterior owing to contraction of the body. Spicules comparatively thick, 3.05–3.3 mm long, each with a transversely striated ala about 20 μ wide along ventral margin and strongly recurved at tip, provided dorsoterminally with a stout barb as described and figured by Boulenger. Gubernaculum 0.32–0.35 mm long. Bursa rather campanulate; dorsal ray (from tip to origin of externodorsal ray) 0.38 mm long, each stem with two outer branches. Dermal vesicle covering genital cone ventrally.

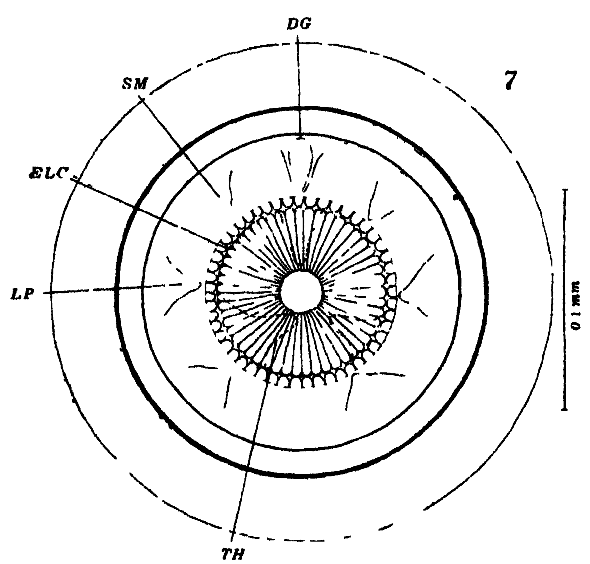


Fig. 7. Head end of female of *Triodontophorus serratus* Looss, 1900, end-on view.

FEMALE. Body 11.5–18.75 × 0.8–1.05 mm. Mouth collar 0.16–0.188 mm in diameter. Leaf-crown containing 47–52 elements. Buccal capsule 0.11–0.13 × 0.15–0.18 mm. Esophagus 0.95–1.3 × 0.2–0.26 mm. Nerve ring, excretory pore and cervical papillae 0.4–0.5 mm, 0.6–0.65 mm and 0.7–0.8 mm respectively from anterior extremity. Tail 0.3–0.33 mm long, vulva 1.0–1.45 mm in front of anus, 1.3–1.8 mm from tail end. Vagina sigmoid, unpaired and paired ovijectors well developed. Eggs elliptical, thin-shelled, 81–105 × 45–51 μ, contained ovum in morula stage when deposited.

The present material agrees well with the description of *Triodontophorus intermedius* by Boulenger. As pointed out by Theiler it is certain that *T. intermedius* Sweet is identical with *T. serratus* Looss.

LITERATURE

Boulenger, Ch. L. Sclerostome parasites of the horse in England. I. The genera *Triodontophorus* and *Oesophagodontus*. Parasit., 8, 1916, 420.

6. *Triodontophorus nipponicus* n. sp.

Text-figs. 9-11;
Pl. XLVII, Figs. 7-10.

Habitat. Colon of *Equus caballus orientalis* and *E. parvus*

Localities. Sapporo and Quelpart Island (Saisyu-to), Korea.

Female. 11–15 × 0.7–0.85 mm, broadest in

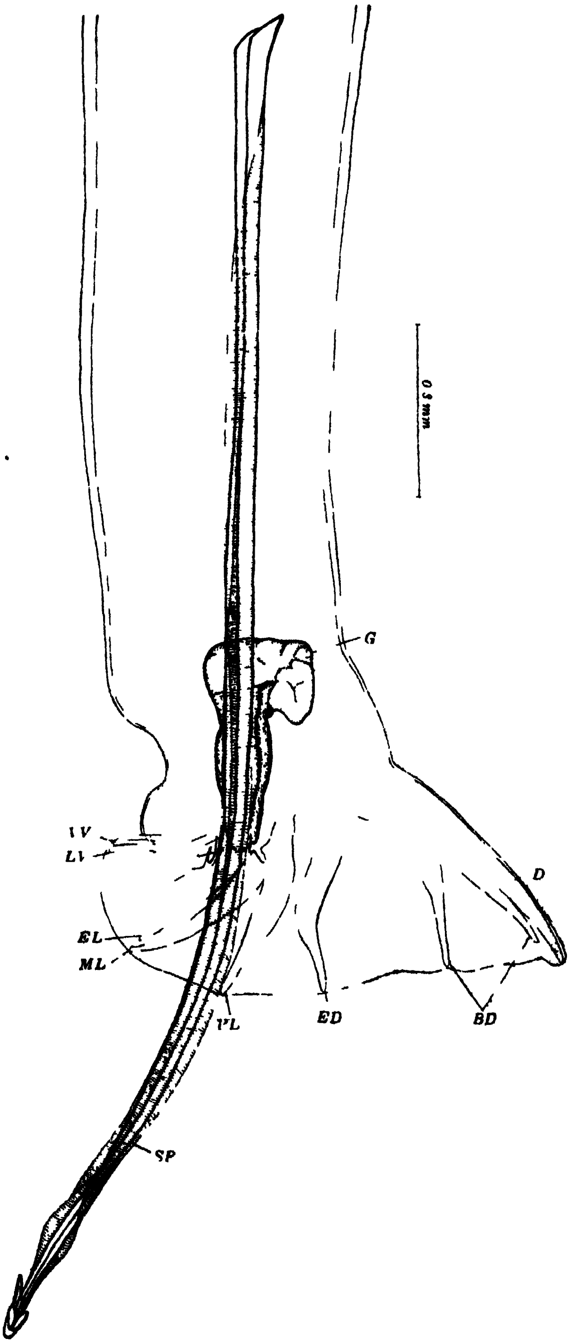


Fig. 8. Posterior extremity of male *Triodontophorus serratus* Looss, 1900, lateral view.

middle region. Cuticle transversely striated throughout. Mouth collar low, somewhat depressed at its margin, where it is 0.18–0.2 mm in diameter. Anterior ends of lateral amphids on a level with bases of spiniform tips of submedian papillae. Each leaf-crown containing 59–64, setiform elements. Buccal capsule subglobular, 0.16–0.18 mm long by 0.17–0.2 mm broad, with 6 (one dorsal, one ventral, four sublateral) petaloid thickenings on outer surface along its anterior marginal portion, dorsal gutter reaching to anterior margin of buccal capsule. Each of the three buccal teeth has three projections, of which the two paired outer have each a few large and small accessory teeth, but the unpaired inner is simple and smaller. Esophagus 0.9–1.5 mm long, with a small anterior and a claviform posterior swelling, latter up to 0.2–0.24 mm in diameter. Nerve ring, excretory pore and cervical papillae 0.6–0.65 mm, 0.66–0.71 mm and 0.65–0.71 mm respectively from anterior extremity in well extended examples 14–15 mm long. Tail conical, 0.13–0.23 mm long. Vulva 0.47–0.65 mm in front of anus, 0.6–0.85 mm from posterior extremity. Vagina short, spirally twisted. Eggs elliptical, 78–105 × 45–57 μ.

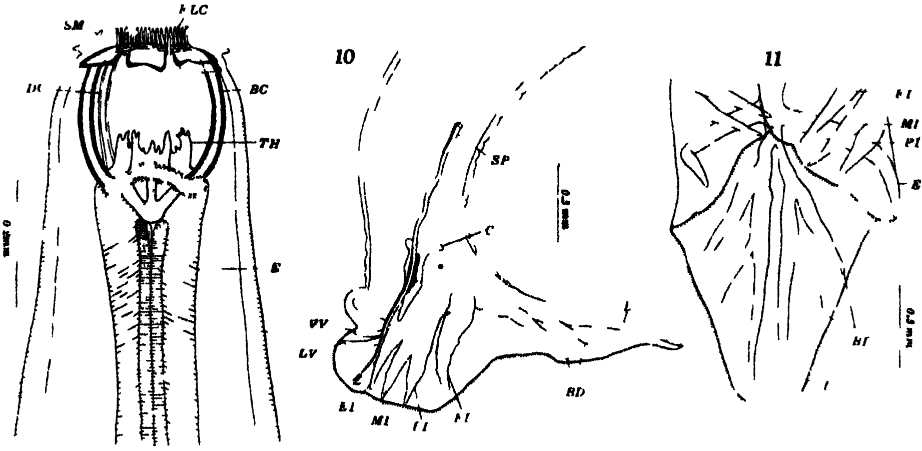


Fig 9-11 *Triodontophorus nipponicus* n sp
Fig 9 Anterior extremity of female, subventral view
Fig 10 Posterior extremity of male, lateral view
Fig. 11 Part of bursa copulatrix showing dorsal ray, ventral view

The following measurements of the male were made on seven contracted specimens from the Korean pony, and some of them are subject to later emendation.

Male. Body 8.1–10.6 × 0.5–0.85 mm. Mouth collar flattened, 0.16–0.19 mm in diameter. The distance between the anterior extremity and the nerve ring, excretory pore or cervical papillae is not given because of their unusually anterior position due to contraction. Leaf-crown elements 57–65 in number. Buccal capsule 0.15–0.18 × 0.17-0.2 mm. Esophagus 0.8–1.0 × 0.16–0.23 mm. Bursa finely striated longitudinally, consisting of symmetrical lateral lobes and a fairly long dorsal lobe, fringed with minute spiniform projection; ventral ray cleft to base, mediolateral and posterolateral rays with common base, both stouter than externolateral, externodorsal ray extending into lateral lobe, curved backward distally, dorsal ray 0.5- 0.65 mm from its tip to origin of externodorsal ray, somewhat constricted immediately before bifurcating, two stems diverging only slightly and terminating near tip of dorsal lobe in a simple point, occasionally in two digitations, each giving off two outer branches of unequal length near its base. Genital cone without spines or anything alike. Spicules filiform, 0.85–0.91 mm long, with 3 (one ventral and two dorsal) barbs at their fused tip. Gubernaculum pistol-shaped, 0.2 0.3 mm long, with a conspicuous transverse incision on ventral side just distal to its middle.

This species differs from the most closely related *T. minor* (Looss, 1900) Looss, 1902, and *T. tenuicallis* Boulenger, 1916, in the number of the leaf-crown elements and in the length of the spicules. In *T. brevicauda* Boulenger, 1916, the leaf-crown contains 60 70 elements, but the tail is extremely short, the buccal teeth are not denticulated, and the spicules are longer.

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Baylis, H. A The fauna of British India, including Ceylon and Burma. Nematoda, Vol 1, 1936, 253 254

Boulenger, C L Sclerostome parasites of the horse in England Parasit, 8(4), 1916, 420-438

Cram, E B A new nematode, *Cylindropharynx ornata*, from the zebra, with keys to related nematode parasites of the Equidae Jour Agric Res 27, 1924, 661 672.

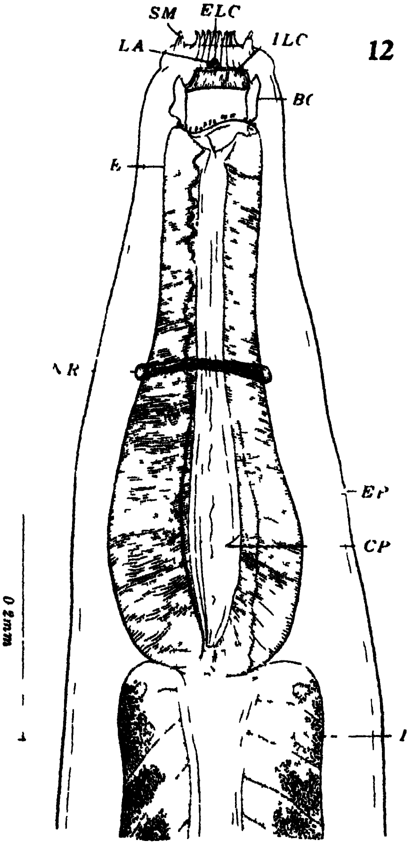


Fig. 12. Anterior extremity of female of *Trichonema subcoronatum* n sp., lateral view.

7. *Trichonema subcoronatum* n. sp.

Text-fig. 12, Pl XVIII, Figs 11 12.

Habitat. Colon of *Equus caballus orientalis* and Korean pony.

Localities. Sapporo and Quelpart Island (Saisyu-to), Korea.

MALE. Body 7.0–8.5 × 0.32 0.35 mm, finely cross-striated except on head and bursa. Mouth collar low, 0.095–0.14 mm in diameter, marked off by distinct constriction. Head 0.11–0.17 mm in diameter, without appreciable neck constriction behind. Nerve ring 0.22–0.31, cervical papillae ·0.36 mm, from anterior extremity· External leaf-crown containing 22 pointed elements projecting as far forward as jointed submedian papillae or a little more. Internal leaf-crown consisting of 74 setiform elements, arising on inner face of buccal capsule 9–15 μ from its anterior end, beyond which it reaches about half its length. Buccal capsule 33–42 μ in length, 66–105 μ in maximum outside diameter at slightly widened anterior part, where the wall thins down abruptly toward the anterior margin but attains a maximum thickness of 6–10 μ at the junction with the cylindrical posterior part. Esophageal funnel with one dorsal and two subventral longitudinal cuticular ridges. Esophagus 0.4–0.63 mm long, slightly narrowed in region of nerve ring, with maximum breadth of 0.11–0.16 mm at posterior swelling. Testis winding anteriorly. Bursa finely striated longitudinally, indistinctly divided into short wide lateral lobes and prominent dorsal lobe; ventral rays cleft to base, mediolateral and posterolateral rays swollen at their greater proximal portion, parallel to each other; externodorsal ray curved dorsally at a wide angle about its middle; dorsal ray 0.55–0.7 mm long from its tip to origin of externodorsal ray, with two outer branches. Genital cone with a transverse row of over 10 spiniform processes 10–15 μ long on a supporting bar, which lies at the posterior end of the dorsal wall of the cone, with the outer ends turned forwards. Spicules filiform, equal, 0.95–1.4 mm long, with barbs as in other members of the genus, Gubernaculum pistol-shaped, 0.19–0.21 mm long, with a ventral incision at about its middle.

FEMALE. Body 8.4–9.4 × 0.32 0.43 mm. Mouth collar 0.098–0.11 mm in diameter, Head not very distinctly marked off by constriction. Nerve ring and cervical papillae 0.27–0.29 mm and 0.38–0.44 mm respectively from anterior extremity. Buccal capsule 42 × 74–78 μ, somewhat wideded anteriorly but cylindrical posteriorly, its wall 8 μ thick at level of insertion of internal leaf-crown. External leaves 22, internal 78 80 in number. Esophagus 0.46–0.5 × 0.12–0.14 mm. Tail 0.12 0.17 mm long, pointed. Vulva 0.075 0.1 mm in front of anus. Eggs elliptical, 84–100 × 15–50 μ.

This species differs from the most closely related *Trichonema coronatum* (Looss, 1900) in the width of the buccal capsule, and probably in the number of elements of the internal leaf-crown, which has not been given for Looss' species by any of the previous authors. In *T. coronatum* the buccal capsule is longer than broad, but in the present species it is about twice as broad as long.

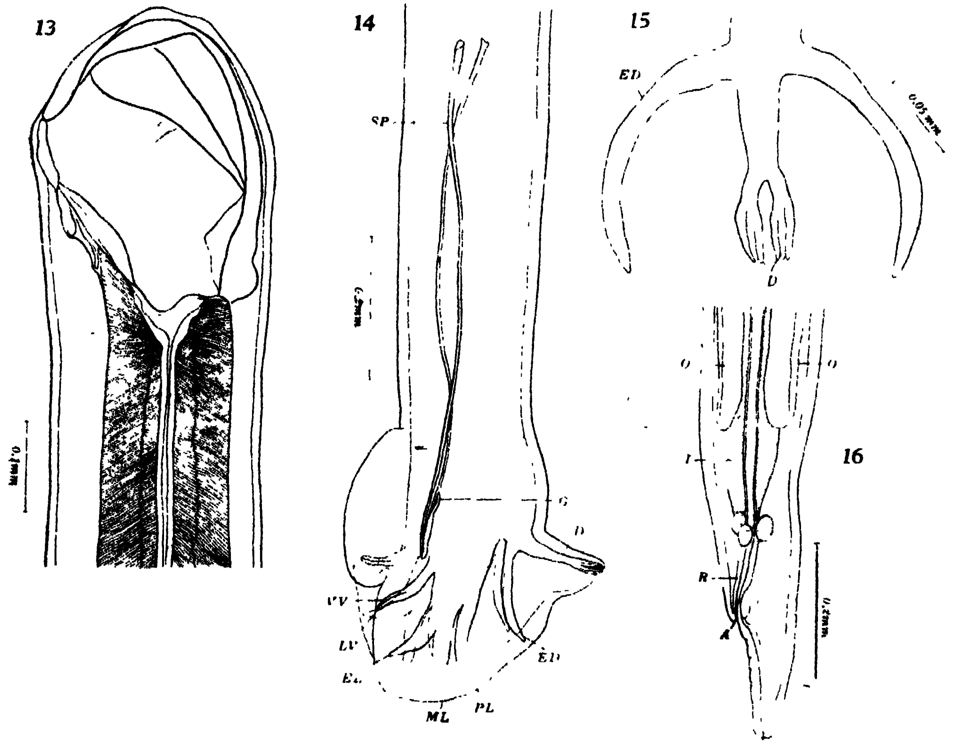
ANCYLOSTOMATIDAE (Looss, 1905)

8. *Uncinaria stenocephala* (Railliet, 1884) Raill., 1885

Text-figs. 13–16

Habitat. Small intestine of *Vulpes vulpes japonicus* Gray.
Locality. Sapporo.
Material. 9 males and 13 females.

MALE. Body 6.3–8.0 × 0.2–0.25 mm. Head curved dorsally with mouth directed anterodorsally. Buccal capsule 126–150 μ long along its ventral surface, 87–96 μ in maximum dorsoventral diameter. The structure of the buccal capsule is shown in fig. 13. Nerve ring, excretory pore and cervical papillae situated 0.4–0.475 mm, 0.42–0.49 mm and 0.42–0.5 mm respectively from anterior extremity. Esophagus 0.71–0.775 × 0.1–0.125 mm, with 3-lobed appendix projecting into intestine. Bursa 0.28–0.34 mm in transverse diameter, divided into a small dorsal lobe and larger inwardly rolled-up lateral lobes; ventral ray cleft for about half its length, mediolateral ray fused with externolateral ray more distally than with posterolateral ray; externodorsal ray slightly arcuate, extending into lateral lobe; dorsal ray 0.08–0.125 mm long from its tip to point of origin of externodorsal ray, bifurcated at about middle, each branch terminating in three slender digitiform processes, of which the outer one is the longest. Large prebursal bulla present. Prebursal papillae subventral, 0.31–0.35 mm from posterior end of bursa. Spicules equal, very narrow, fused at pointed distal end, 0.69–0.78 mm long; gubernaculum attenuated proximally, 90–110 μ long, 15–20 μ broad distally.



Figs. 13–16. *Uncinaria stenocephala* (Raill., 1884) Raill., 1885.
Fig. 13. Anterior extremity of female, lateral view.
Fig. 14. Posterior extremity of male, lateral view.
Fig. 15. Dorsal ray of bursa copulatrix, ventral view.
Fig. 16. Posterior extremity of female, lateral view.

FEMALE. Body 7.8–9.6 × 0.22–0.3 mm. Buccal capsule 159–180 μ long along ventral margin, 114–120 μ in maximum outside diameter, which is somewhat greater laterally than dorsoventrally. Nerve ring, excretory pore and cervical papillae 0.46–0.58 mm, 0.48–0.59 mm and 0.45–0.59 mm respectively from anterior extremity. Esophagus 0.72–0.9 × 0.12–0.15 mm. Tail 0.13–0.21 mm long, tapering to a blunt point tipped with a bristle 10–25 μ long with a pair of inconspicuous lateral papillae 24–45 μ from its blunt-pointed end. Vulva more or less prominent, dividing body length in ratio of 1.6–1.9 : 1. Eggs elliptical, thin-shelled, 75–90 × 39–51 μ; contained ovum segmented.

It is to be noted that the nerve ring, excretory pore and cervical papillae vary more or less in their relative positions in different specimens as pointed out by Ransom.

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Fülleborn, F. Bemerkungen über die Identifikation von „Hakenwürmern". Arch Schiffs-u Tropenhyg. 28, 1924, 12 15

Ransom, B. H. Hookworms of the genus *Uncinaria* of the dog, fox and badger Proc. U S Nat. Mus, Vol. 65, Art. 20, 1924, 3-4.

9. *Bunostomum trigonocephalum* (Rud., 1808)

Text-figs. 17–18

Habitat. Small intestine of *Ovis aries*

As shown in the following table the present material (6 males and 4 females) agrees well with Baylis' from India.

	Cameron (1923)	Baylis (1936)	Present author
Body length	♂ 14.5–15.5(16.5) ♀ 22 24(26)	11 17 14–26	12.3 15.6 16 22
Length of buccal capsule	—	0.17 0.225	♂ 0.2 ♀ 0.225 0.26
Dorsoventral diameter of buccal capsule	—	0.15–0.175	♂ 0.16–0.165 ♀ 0.2 0.225
Nerve ring from head end	—	0.6	0.55–0.75
Cervical papillae from head end	—	0.6–0.75	0.6–0.7
Excretory pore from head end	—	0.6–0.75	0.7–0.87
Length of esophagus	1.3	0.8–1.45	1.0 1.4
Spicules	0.65	0.6–0.75	0.65–0.7
Tail of female	—	0.25–0.4	0.3–0.35
Vulva from head end	—	5.5–8.0	6.3–8.0
Eggs	—	75–85 × 38–50 μ	78–90 × 42–54 μ

The transversely striated membrane which Cameron regards as a spicular

sheath, is nothing but a spicular ala and extends spirally, giving the gently undulating spicule a twisted appearance.

LITERATURE

Baylis, H. A. Nematoda I. (Fauna of British India), 1926, 331-335.

Cameron, T. W. M. The anatomy of *Monodontus trigonocephalus* (Rud.) of sheep. Jour. Helm. Vol 1, 1923, 99-117

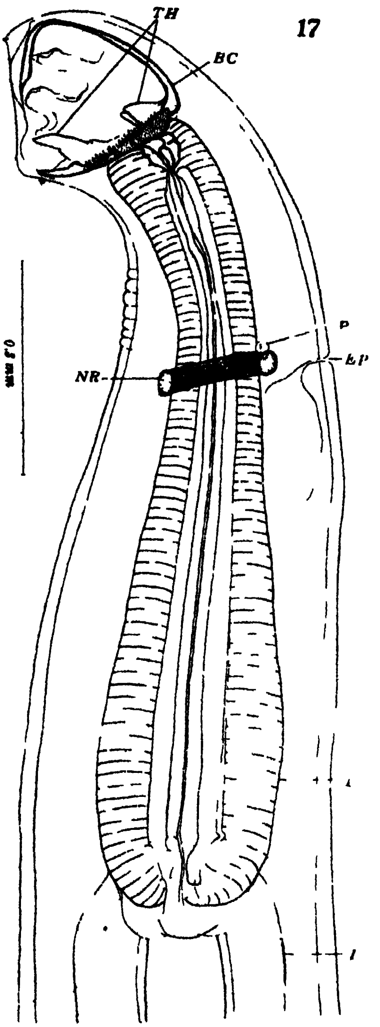

Fig 17 Anterior extremity of female of *Bunostomum trigonocephalum*, lateral view.

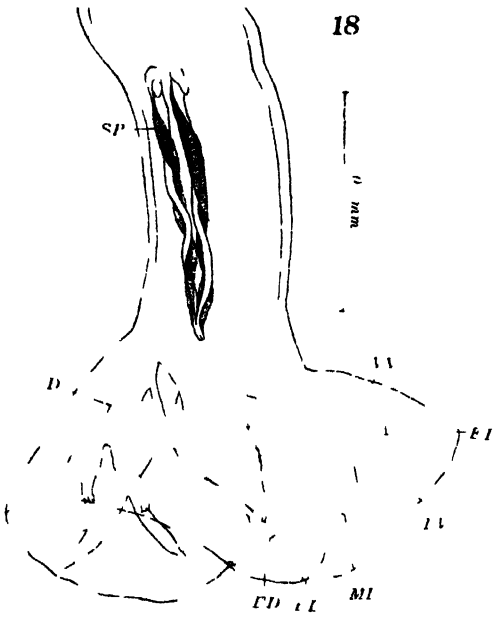

Fig. 18 Posterior extremity of male of *Bunostomum trigonocephalum*, dorsolateral view

OXYURIDAE Cobbold, 1864

10. *Oxyuris equi* (Schrank, 1788) Blanch., 1849

Text-figs. 19-21.

Habitat. Large intestine of *Equus caballus orientalis*.
Locality. Kyoto abattoir.
FEMALE. Body 28-100 × 1.4-3.5 mm, gradually tapering posteriorly and

terminating in a whip-like tail. Cuticular striations lacking on head and greater posterior part of tail, simple at commencement and termination but elsewhere each is split up into three. On each side of the head end there are two rosettes of half-chitinous rodlets separated one from the other by the lateral line which terminates in an amphid on the lateral margin of the mouth aperture. This rosette is designated by Yorke and Maplestone as "head papilla", but whether it is a true sensory organ or not I cannot state with certainty. Vestibule hexagonal in end-on view, 0.11 0.15 mm in diameter, provided at its entrance with six lips, each of which is reinforced by half-chitinous network in relief, and posteriorly with six membranous ledges; buccal capsule 0.18 0.23 mm in diameter, fortified at its entrance with three (one ventral and two subdorsal) coat-hanger-like chitinous bars, but immediately behind these the lumen becomes triradiate and has a thin chitinous wall, from which three (one dorsal and two subventral) club-shaped processes (esophageal teeth of Yorke and Maplestone) project inwards and then curve forwards and reach to the entrance of the capsule, each bearing on the medial side a wavy transverse row of 15 16 short digitiform teeth. The triangular base of the buccal capsule is fringed except at the corners with a row of simple or branched bristles, about 20 for each base. The bristles are the longest at the middle of the base just behind the base of the club-shaped dentigerous process mentioned above and become shorter toward the corners. The esophagus with a comparatively wide triradiate lumen throughout is 2.1 -3.5 mm long, 0.32–0.75 mm wide at its anterior double swelling, 0.25 0.45 mm wide at the narrowest part and 0.47–0.85 mm in maximum diameter at the posterior bulb. On the inner surface it has three pairs of longitudinal, bank-like fields of exceedingly small, file-like spines, and three pairs of longitudinal rows of several arcuate chitinous ribs, with the concave sides opposite each other; the fellows of the same pair of these structures are continuous at the commencement. The spiny fields become

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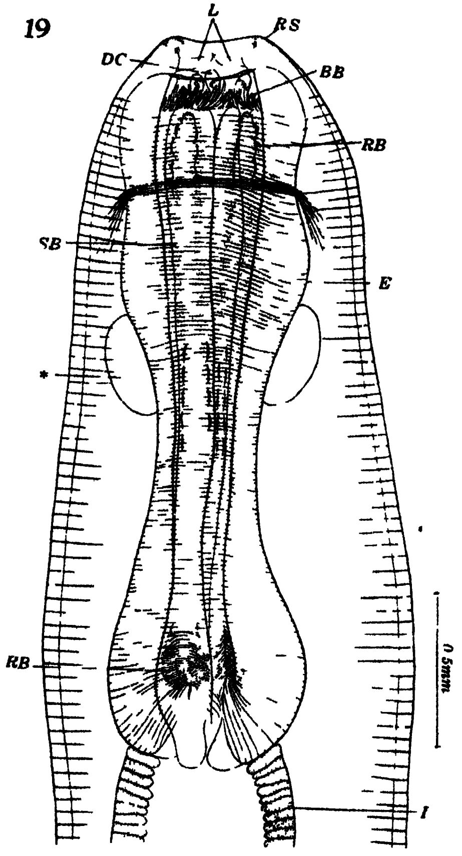
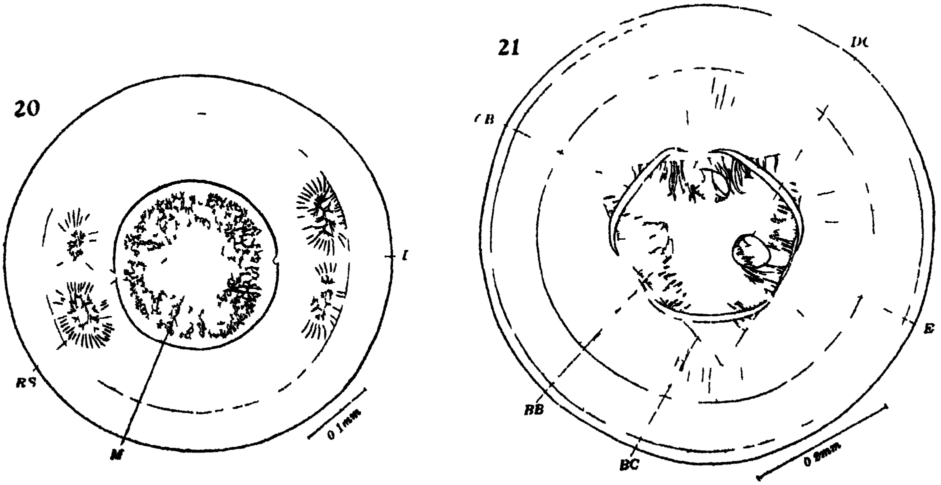


Fig. 19 Anterior extremity of female of *Oxyuris equi*(Schrank, 1788), dorsal view. *Structure of unknown nature.

gradually indistinct posteriorly and disappear at the posterior end of the anterior double swelling of the esophagus, whereas the ribs are confined to the anterior half of this double swelling. At the anterior end of the narrow portion of the esophagus, however, three pairs of longitudinal rows of several, almost lineally stretched ribs appear again and extend backward for a distance of 0.5–0.7 mm. In place of these longitudinal ribs three plaques of fine, very closely set, transversely arcuate ribs, about 40 ribs for each plague, are seen at the center of the esophageal bulb, though few of the ribs at the posterior end of the plaque are longitudinal. The posterior end of the esophagus projects slightly into the intestine in the form of three rounded lobes. The intestine is dorsal for the most part but proceeds ventrally as it approaches the rectum. It is sometimes distended with the ingesta of the host, which gives it a dark brownish grey or even blackish appearance. Rectum lined with thick cuticle, 0.65–2.0 mm long. Tail whip-like, very variable (3.4–5.5 mm) in length according to age of individuals.



Figs 20–21 Anterior extremity of female of *Oxyuris equi* (Schrank, 1788)
Fig 20. End-on view Fig 21 Transverse section through buccal capsule.

Each filiform ovary, originating in the anal region or thereabout, proceeds forward along with the descending uterus, into which it continues near the vulva by means of a much narrower germiduct forming two or three longitudinal loops. The anterior portion of the descending uterus may function as receptaculum seminis, but in view of the contents, it is certain that this descending duct is a part of the uterus, hence I propose to call it "descending uterus". The two descending uteri extend into the tail and unite with each other to form a short common duct. This in turn soon joins the ascending uterus a short distance in front of the posterior end of the latter which lies 0.8–5.0 mm from the posterior extremity of the body. The ascending uterus, provided with circular muscle, may be strongly distended with eggs as reservoir for them, especially at its distal portion. It turns ventrad near the vulva and continues into a short vagina provided with strong longitudinal and circular muscles. Vulva 7.8–10.5 mm from head end. Uterine eggs symmetrically or slightly asymmetrically elliptical, with distinct polar plug, 84–96 × 40–45 μ; egg shell about 4 μ thick; contained ovum not yet segmented. There is a long tubular excretory vesicle on the ventral side in front of the vulva; it narrows somewhat at about the middle, where it opens to the outside, so that it may be divided into two unequal club-shaped portions with the swollen ends directed oppositely.

MALE. Body 8.85-11 × 0.6–0.9 mm, cross-striated throughout at maximum interval of about 30 μ. Excretory pore 2.6–3.0 mm from anterior extremity. Esophagus 1.35–1.5 mm long, 0.26–0.31 mm broad at anterior double swelling, 0.32–0.4 mm broad at posterior bulb. Spicules slender, 0.17–0.23 mm long. Two pairs of alate caudal papillae, one ventrally and the other dorsally as illustrated by Morke and Maplestone.

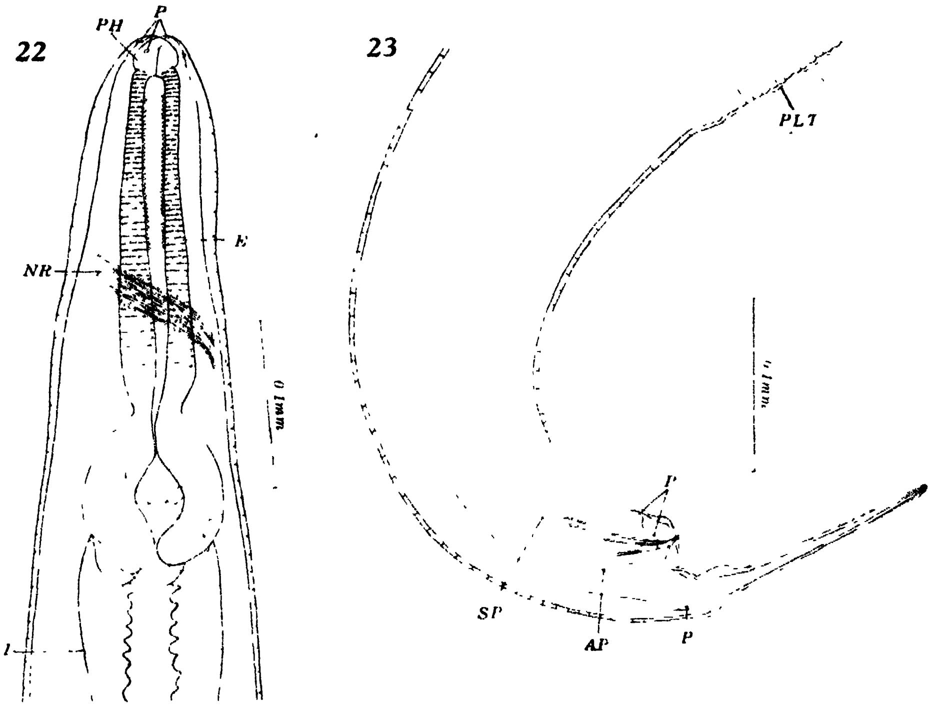
11. *Syphacia montana* n. sp.

Text-figs. 22–23; Pl. XLVIII, Figs. 14 15.

Habitat. Ceca of *Clethrionomys smithii* (type host) and *Microtus montebelli*.

Locality and date. Miure. Kiso; May 2, 1912.

MALE. Body 1.8–2.0 mm in length, with maximum breadth of 0.15 mm in region of middle mamelon, whence it tapers gradually toward both extremities. Posterior half of body rolled up ventrally, with the tail process directed toward the first mamelon. Cuticle cross-striated throughout, swollen from behind lips to region of nerve ring, where it is 80-85 μ in dorsoventral diameter. In the esophageal region the cuticle shows a number of longitudinal striations. Nerve ring and excretory pore 0.13 0.14 mm and 0.41–0.45 mm respectively from head end. Each lip with a small papilla on outer surface of its anterior end and a similar one on each side of its base. Mouth leading directly into small conical pharyngeal portion; esophagus proper cylindrical, armed with a longitudinal row of about 30 conical teeth on each of three internal surfaces at its anterior half but smooth elsewhere; posterior bulb 80–84 × 72–75 μ, with 3-lobed appendix projecting into intestinal lumen. Entire length of esophagus (including pharyngeal portion and posterior bulb) 0.27 mm, about one seventh of body length. There are three transversely striated mamelons about 0.12 mm long at interval of 0.075–0.15 mm and 0.15 mm respectively, the anterior end of the first being 0.16 mm behind the excretory pore, and the posterior end of the third 0.3 mm in front of the cloacal aperture. Testis turning backwards at level of first mamelon or immediately behind it. Tail 0.17 mm long, with a posterolaterally directed nodular process on each side of its base, behind which it tapers abruptly to a subulate process 0.15 mm long. In front of the cloacal aperture is a conical unpaired papilla. Of the three pairs of anal papillae the middle lies on a level with the unpaired pre-anal papilla, the posterior on the posterolateral surface of the nodular postanal process



Figs. 22 23. Male af *Syphacia montana* n. sp.
Fig. 22. Anterior extremity, lateral view.
Fig. 23. Posterior extremity, lateral view.

mentioned above. Spicule slender, 81–87 μ long, 5–6 μ broad at its ventrally curved base; accesory piece 44–45 μ in length including its terminal barb.

FEMALE. Body 3.7–5.9 × 0.25–0.3 mm; lateral alae very narrow, extending almost entire length of body. Head 35–54 μ in diameter at level of basal lip papillae. Nerve ring 0.1–0.16 mm from head end; excretory pore 0.39–0.55 mm from head end, 0.15–0.28 mm in front of vulva. Esophagus (including pharynx and posterior bulb) 0.3–0.4 mm long, $\frac{1}{15}$ to $\frac{1}{12}$ of body length, armed with teeth as in male; posterior bulb 78–102 × 75–102 μ. Tail subulate, 0.45–0.9 mm long, $\frac{1}{8}$ to $\frac{1}{6}$ of body length. Vulva 0.65–0.775 mm from head end, 0.2–0.46 mm behind esophageal bulb, dividing body length in ratio of 1 : 4.6–7.6, often very prominent. Eggs flattened on one side, 108–125 × 29–40 μ.

This species differs from *S. obvelata* (Rud.) in the length of the esophagus and of the accessory spicule, and from *S. muris* (Yamaguti, 1935) in body size as well as in the lengths of the spicules and of the eggs. In Rudolphi's species the length of the esophagus including the bulb is one ninth of the body length in both sexes.

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Yamaguti, S. Studies on the helminth fauna of Japan. Part 35. Mammalian nematodes, Jap. Jour. Zool, 9(3), 1941, 420.

SPIRURIDAE Oerley, 1885

12. *Habronema microstoma* (Schneider, 1866) Ransom, 1911

Text-figs. 24–26; Pl. XLVIII, Figs. 16–18.

Habitat. Stomach of *Equus caballus orientalis*

Locality. Sapporo.

MALE. Body slender, 15–20 mm long by 0.3–0.4 mm broad, with posterior end rolled up ventrally. Cuticle cross-striated throughout. Cervical papillae and nerve ring 0.23–0.33 mm and 0.31–0.35 mm respectively from head end. Excretory pore immediately behind nerve ring. Head 75–84 μ in diameter. Tail 0.35–0.42 long. Lateral lip strongly constricted at base. Buccal capsule divided into two portions of different structure; the anterior por-

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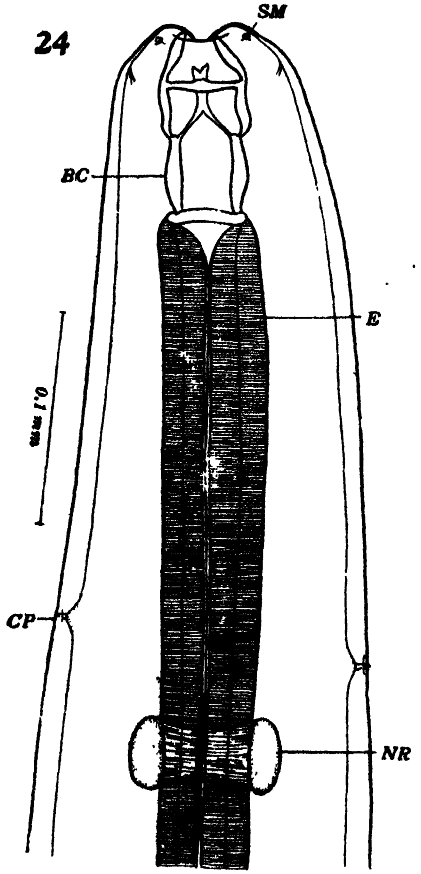

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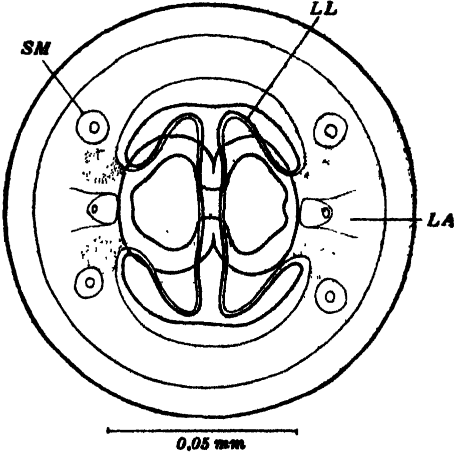

Figs. 24–25. *Habronema microstoma* (Schneider, 1866), ventral view.

Fig. 24. Anterior extremity of male dorsoventral view.

Fig. 25. Head end of female, end-on view.

tion is divided into two lateral chambers 24–30 μ in dorsoventral diameter. The partition between these two chambers forms a longitudinal ridge, which projects forwards and inwards as a prominent blunt tooth with rough surface, and decreases in height posteriorly. The posterior portion of the buccal capsule is bulbous or cylindrical, 37–47 μ in diameter, with its chitinous wall attaining a maximum thickness of 6–9 μ at the equatorial level. At the base of this portion 50–100 μ from the head end is a chitinous ring, which is 36–51 μ in diameter, and is directly followed by the esophagus. Esophagus 3–3.6 mm long, 0.12–0.16 mm broad near its posterior end, to which a valvular apparatus is attached.

On the posterior ventral surface of the body as well as on the caudal alae the cuticle shows transversely incised longitudinal striations. Caudal alae about 0.85 mm long by 0.325 mm broad, with 6 pedunculate papillae on each side; on the right the four anterior papillae lie one close behind another near the cloacal aperture, with the third or the fourth level with this aperture, and the posterior two lie one obliquely behind the other near the tail end, while on the left the four anterior papillae are arranged like the corresponding left ones, but a little more anteriorly, with the fourth distinctly in front of the cloacal aperture, the fifth lies immediately posterosinistral to the cloacal aperture, a little medial to the others, and the sixth 0.27–0.31 mm from the tail tip. On the ventral side of the tail end there are 3 pairs of very small sessile papillae close together. Right spicule 0.34–0.39 mm long, left spicule 0.75–0.87 mm long; gubernaculum 60–65 μ long, fluted on ventral side, extending on the left about 40 μ further forward than on the right.

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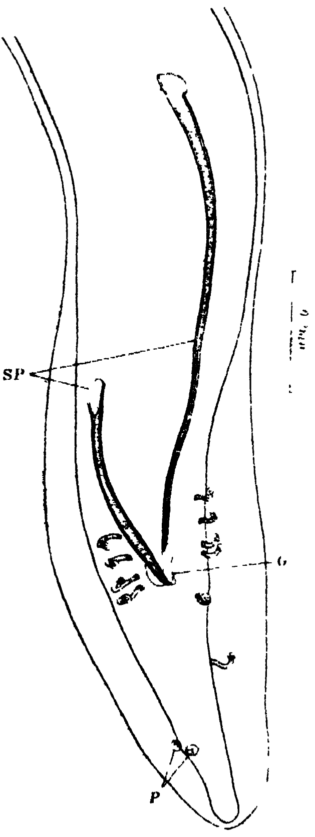

Fig. 26. Posterior extremity of male of *Habronema microstoma* (Schneider, 1866), ventral view.

Female. Body 19–24 × 0.38–0.55 mm. Tail gently curved dorsally and tapering to a blunt point, 0.38–0.49 mm long. Cervical papillae and nerve ring 0.26–0.31 mm and 0.33–0.375 mm respectively from head end. Head 87–100 μ in diameter, lateral lip about 50 μ broad at its terminal enlargement, about 40 μ broad at its constricted base; median dentiform projections blunt, about 12 μ long. Posterior portion of buccal capsule bulbous or cylindrical, 45–51 μ in diameter, its wall 6–9 μ thick at equatorial level; basal ring 42–57 μ in diameter, 90–108 μ from head end. Esophagus 3.1–3.95 × 0.13–0.17 mm. Anterior re-

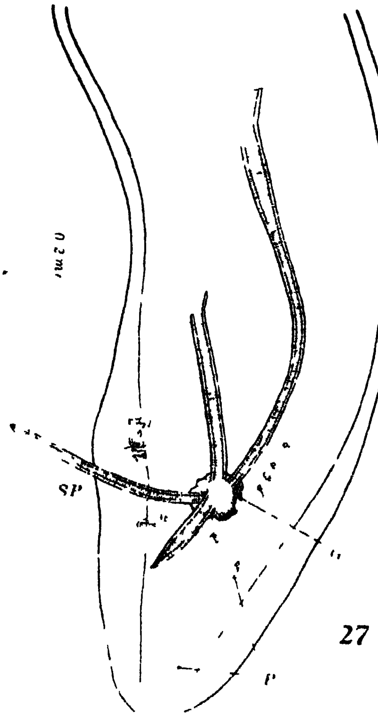

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Fig. 27. Posterior extremity of male of *Habronema tyosenense* n. sp., ventral view

ceptaculum seminis 1.75–2.5 mm in front of vulva, posterior one 0.87-2.9 mm in front of cloacal aperture. Vagina directed backwards from vulva, 0.5–0.75 × 0.07–0.09 mm, provided outside with a thick (up to 27 μ) coat of circular muscles, which forms near the genital pore a bulb-like mass 0.15-0.2 mm in diameter. The vagina passes through this bulb excentrically and leads into a vulvar tube which is 90 μ long and provided with a chitinous lining. At the opening of this tube is a glandular body about 70 μ in diameter. Vulvar opening small, not prominent, dividing body length in ratio of 1 : 1.5-2.0. Embryos sheathed, about 110 μ long by 6 μ broad as fixed in alcohol and measured in water.

13. *Habronema tyosenense* n. sp.

Text-fig. 27, Pl XLVIII, Fig. 19 and Pl XLIX, Fig. 20.

Habitat. Stomach of Korean pony.

Locality. Quelpart Island (Saisyu-to), Korea.

MALE. Body whitish, slender, 13.5 × 0.325 mm, finely cross-striated throughout except on ventral side of posterior extremity. From a point 0.9 mm in front of the cloacal aperture to the tip of the tail the ventral cuticle forms numerous fine longitudinal ridges, of which the precloacal portion is transversely incised and assumes a serrate appearance. Lateral flanges narrow, commencing immediately behind cervical papillae, which are situated 0.29 mm from the anterior extremity. Lateral lip 42 μ in dorsoventral diameter, constricted on each side at base. Anterior portion of buccal capsule 45 μ long, posterior cylindrical portion 39 μ in diameter, its wall 6–7.5 μ thick. Median denticular ridges prominent, not very sharp. Esophagus 2.2 mm in entire length (anterior muscular portion 0.3 mm), 0.114 mm wide at posterior glandular portion. Tail 0.26 mm long. Of the six pairs of pedunculated subventral anal papillae four are pre-anal and two post-anal. Three pairs of very small sessile papillae are on the ventral side of the tail end. Right spicule 0.37 mm long, left spicule 0.8 mm long; gubernaculum cushion-shaped. On the left edge of the cloacal aperture is a cuticular shield 40 μ long by 28 μ broad, and on the anterior edge beside the shield is a cuticular rod 30 μ long by 9 μ broad. A similar rod is seen immediately behind the cloacal aperture.

FEMALE. Body whitish opaque, 17 mm long by 0.475 mm broad. Cervical papillae and nerve ring 0.28 mm and 0.31 mm respectively from anterior extremity. Buccal capsule 80μ long, its anterior portion 45μ in length, posterior portion 36μ in length including basal ring which is 50μ in diameter. Anterior muscular portion of esophagus 0.375 mm long, posterior glandular portion 2.6 mm long by 0.15 mm broad. Tail blunt 0.26 mm long, curved dorsally in form of a hook. Vulva dividing body length in ratio of 1:2.1. Vagina looped immediatly behind vulva.

This species differs from the most closely related *H. microstoma* (Schneider, 1866) and *H. clarki* Foster et Chitwood, 1937, in the arrangement of the anal papillae, the position of the vulva, etc. In *H. clarki* the anterior margin of the lateral lip is 3-lobed according to the original authors but in the present species it is slightly arcuate and entire.

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14. *Protospirura muris* (Gmelin, 1890) Seurat, 1915

Text-Fig. 28.

Habitat. Stomach of *Clethrionomys smithii* and *Apodemus geisha geisha* (Thomas)

Locality and date. Sintaka at the foot of Mt. Ontake; August 11, 1942.

MALE. Body 21-25 × 0.8-0.9 mm. Head 0.2 mm in diameter at level of anterior end of cylindrical portion of buccal capsule which is 0.16-0.18 mm long by 63-70μ broad. Nerve ring, cervical papillae and excretory pore 0.4-0.45 mm, 0.38-0.4 mm and 0.55-0.58 mm respectively from head end. Esophagus 3.7 × 0.32 mm, with three-lobed posterior appendix projecting very prominently into intestine. Tail 0.55-0.65 mm long, with four pairs of minute sessile papillae on ventral side of its posterior end. 4 pre-anal and 2 post-anal pairs of pedunculated papillae. Right spicule 1.01 mm long; left spicule slender, 0.89-1.0 mm long. Gubernaculum 80μ long.

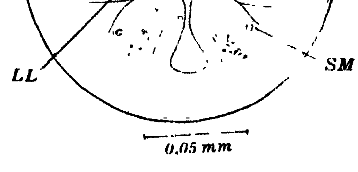

Fig. 28. Head end of *Protospirura muris* (Gmelin, 1890), end-on view.

FAMALE. Body 34-44 × 1.0-1.6 mm. Head 0.25-0.33 mm in diameter. Buccal capsule consisting of funnel-shaped vestibule and cylindrical posterior portion 0.125-0.23 mm long, with thick muscular coat. Nerve ring, cervical papillae and excretory pore 0.45-0.55 mm, 0.425-0.55 mm and 0 56-0.78 mm respectively from head end. Esophagus 3.75-4.8 × 0.31-0.42 mm. Tail 0.3-0.45 mm long. Vulva at about junction of anterior with middle third of body. Eggs elliptical, thick-shelled, embryonated, 54–60 × 27–33 μ.

Except for the four submedian papillae and the two lateral amphids there is a pair of minute blunt-conical cuticular protuberances on each lobe of the lips near its tip. The middle lobe of each lateral lip has two or three conical teeth along its truncate end, while the submedian lobe has a single pointed tooth on the inner surface of its tip.

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FILARIIDAE (Cobbold, 1864)

15. *Setaria equina* (Abildg., 1789) Railliet et Henry, 1911

Text-fig. 29.

Habitat. Abdominal and thoracic cavities of *Equus caballus orientalis.*

Localities. Kyoto and Sapporo.

Material. Three males and four females.

MALE. Body spirally twisted posteriorly, 58–64 × 0.5–0.53 mm Cuticular peribuccal ring cosisting of inconspicuous lateral lips and very prominent, truncate, median processes. Of the four submedian head papillae the anterior two are prominent horn-like cuticular processes and lie about halfway between the peribuccal ring and the posterior submedian papillae. The latter are less prominent, rather flat and lie on a level with the lateral amphids. Nerve ring and cervical papillae 0.2–0.25 mm and 0.45–0.5 mm respectively from head end. Anterior muscular portion of esophagus 0.5–0.75 × 0.11–0.13 mm, somewhat constricted by nerve ring; posterior glandular portion 7.9–10 × 0.27–0.3 mm. Tail bluntly pointed, 0.11–0.12 mm long, slightly constricted at about its middle, without cuticular lateral process as observed in *Setaria labiatopapillosa*, contrary to Thwaite's description*. The pre-anal and post-anal ventral surface of the body, espcially the circumcloacal area, is covered with minute refractive graunles. Four pairs of pre-anal and six pairs of post-anal, papillae are present, including one pair of lateral papillae for the former and two pairs for the latter. The anterior lateral post-anal papilla lies immediately behind the tail constriction and the posterior, smallest of all, at the tip of the tail.

A single median papilla-like structure may be present on the anterior margin of the cloacal aperture. Right shorter spicule 0.21–0.24 mm long. Left longer spicule 0.7–0.71 mm in entire length including terminal filament; its proximal half is tubular and 50–65 μ in diameter at the enlarged proximal end, the distal half consists of a spear-shaped chitinous axis and a membranous sheath, whose distal end is truncate except on the right, where it tapers abruptly to a fine filament about 45 μ long. Between these two portions of different structure is intercalated a half-spiral of a corkscrew.

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* It seems very probable that Thwaite regards the lateral post-anal papilla as cuticular appendage.

FEMALE. Body 86–100 × 0.8–1.05 mm. Nerve ring and cervical papillae 0.24–0.31 mm and 0.4–0.63 mm respectively from head end. Anterior muscular portion of esophagus 0.8–0.95 × 0.15–0.18 mm, posterior glandular portion 10.5–12.6 × 0.1–0.5 mm. Tail 0.35–0.5 mm long, with a pair of conical lateral processes near its terminal knob. Vulva 0.58–0.8 mm from head end. Embryos 0.225–0.25 mm long by 5 μ thick

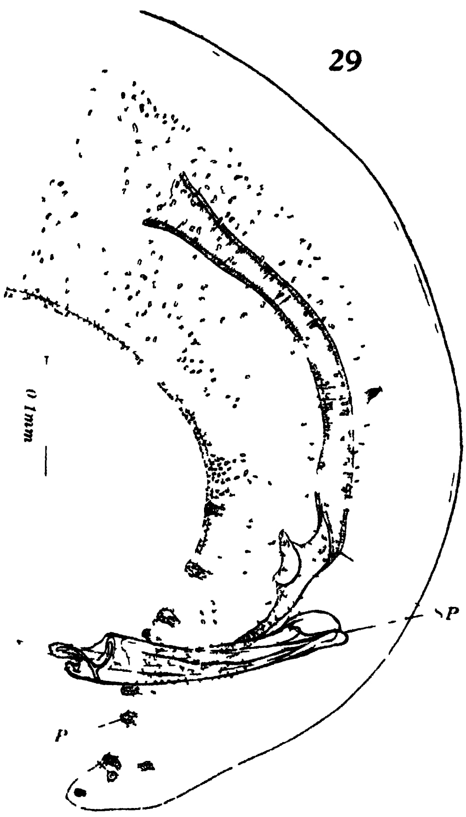


Fig. 29 Posterior extremity of male of *Setaria equina* (Abildg., 1789), lateral view

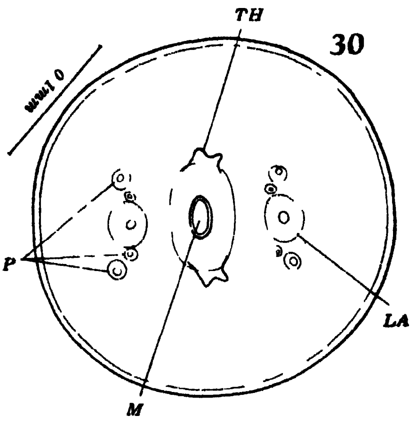
16. *Setaria labiatopapillosa* (Alessandrini, 1838)

Text figs. 30–31; Pl. XLIX, Fig. 21

Habitat. Body cavity and subcutaneous or intermuscular connective tissue of *Bos taurus domesticus* Gmelin.

Locality. Kyoto abattoir.

MALE. Body slender, forming two spiral turns at posterior extremity, 36–57 × 0.4–0.55 mm. Cuticle smooth, up to 20 μ thick. Mouth aperture dorsoventrally elongated oval or elliptical; lateral lips more or less convex or conical, occasionally trapezoidal in lateral view; dorsal and ventral cuticular projections very prominent, distinctly notched at middle of anterior margin, 65–70 μ apart from end to end. On each side of the mouth there are two pairs of smaller and two pairs of larger, submedian papillae, and a pair of lateral amphids as shown in fig. 30. Nerve ring and cervical papillae 0.2–0.3 mm and 0.38–0.6 mm respectively from head end. Anterior muscular portion of esophagus 0.45–0.88 mm long, posterior glandular portion 5.0–7.85 mm long. Tail blunt-pointed, 0.18–0.21 mm long, with a pair of blunt, horn-like, lateral processes at some distance from its end. Besides one pre-anal and two postanal, unpaired median papillae there are altogether 8 pairs of caudal papillae,



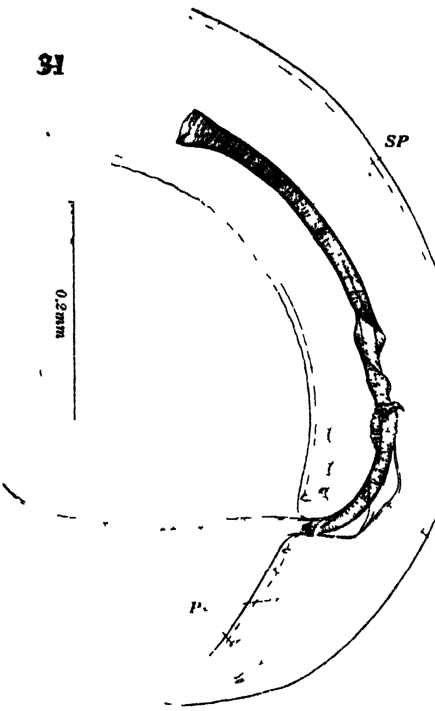


Fig. 30. Head end of female of *Setaria labiatopapillosa* (Alessandrini, 1838), end-on view.

Fig. 31. Posterior extremity of male of *Setaria labiatopapillosa* (Alessandrini, 1838), lateral view.

of which three are pre-anal[1], one is ad-anal[2] and four are post-anal, two of the latter being smaller than the others and lying laterally immediately in front of the base of the hornlike process mentioned above. Right shorter spicule shaped like a chopping knife, 0.1–0.15 mm long ; left longer spicule up to 0.7-0.75 mm in length including terminal filament whose proximal portion shows a sheath-like structure; the greater chitinous portion of this spicule 0.34 0.4 mm long is tubular and thin-walled proximally, then corkscrew-like and finally corrugated transversely.

Female. Body 37–164 × 0.4–0.88 mm, tapering posteriorly and forming one spiral turn. Dorsal and ventral cuticular projections of lips 75–180 μ apart from end to end. Nerve ring 0.19–0.35 mm, cervical papillae 0.3-0.6 mm, from head end. Anterior muscular portion of esophagus 0.52-1.1 mm long, posterior grandular portion 5.2-11.5 mm long. Tail 0.3–0.63 mm long, with a pair of lateral processes near its terminal knob which is coverd with minute spines. Vulva 0.35-0.83 mm from head end. Embryo 0.19–0.2 mm long, inclosed in a sheath about 0.3 mm long.

It is to be noted that the large spicule of my specimens is different in length from that of Thwaite's. This difference is, however; due to the fact that Thwaite has overlooked the terminal portion of the spicule.

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1) and 2) The ad-anal papilla may be shifted anteriad, so that there may be four pre-anals present. Occasionally 6 pre-anals may be found on one side.

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PSEUDALIIDAE Railliet, 1916

17. *Stenurus globicephalae* Baylis et Daubney, 1925

Text-figs. 32–34; Pl. XLIX, Figs. 22–28.

Habitat. Accessory nasal cavity of *Globiocephalus scammoni* Cope.

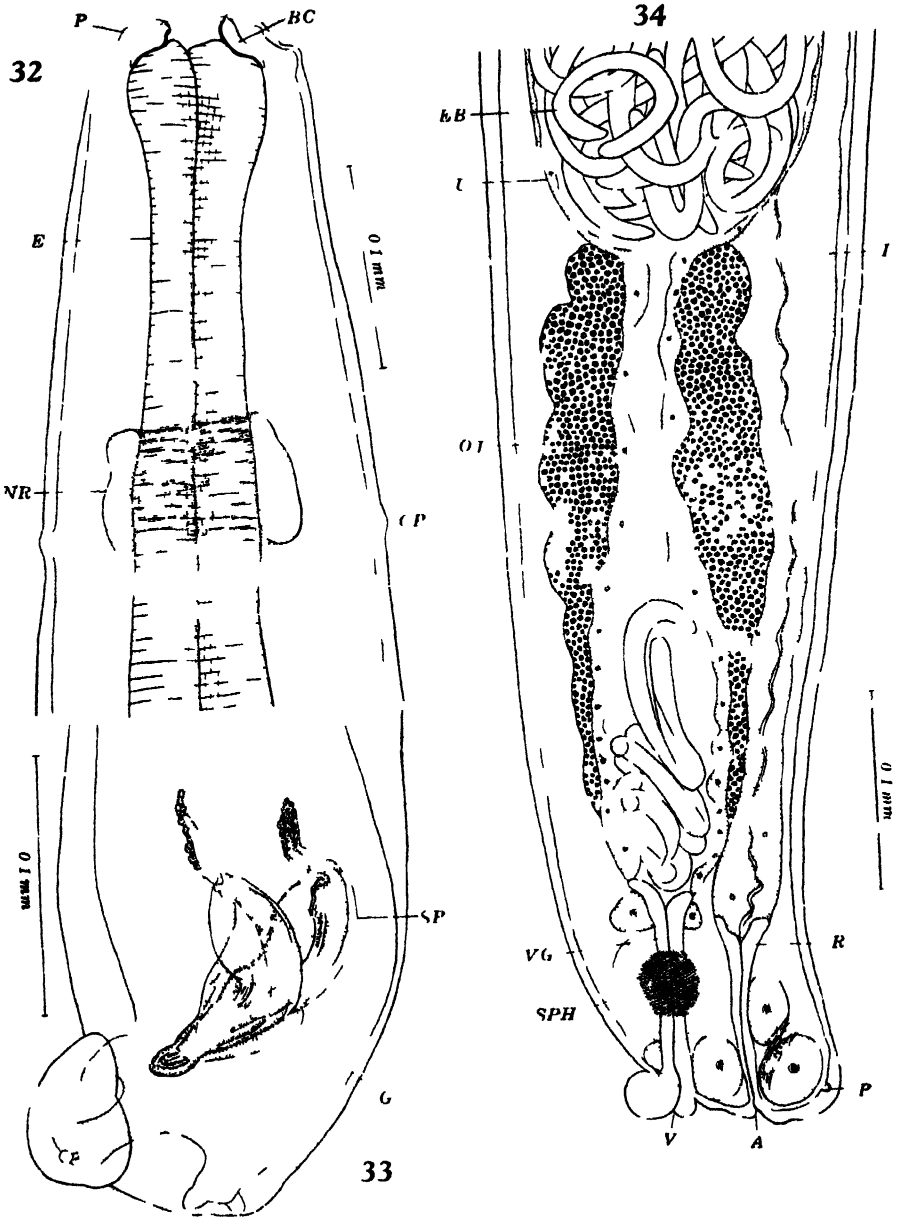
Locality. Taizi, Wakayama Prefecture.

Material. Numerous mature males and females.

MALE. Body slender, 18–22.5 mm in length, with maximum breadth of 0.4 mm in greater middle portion, markedly attenuated in region of ductus ejaculatorius, where the dorsal and lateral parietal muscles run obliquely ventroposteriad. Tail 50–75 μ long, curved ventrad, provided with characteristic bursa described below. Cuticle smooth, without lateral flanges. Mouth aperture not exactly circular, but rather 3-lobed in end-on view, one lobe being dorsal, others subventral. Head with two circles of two lateral and four submedian papillae each; anterior circle about midway between mouth aperture and posterior circle; anterior papillae smaller than posterior, lateral papillae sometimes inconspicuous. The mouth aperture leads directly into a shallow, thick-walled, buccal capsule 9–12 μ in length and 24–50 μ in inside diameter at its anterior end. In optical section the wall of the buccal capsule is divergent posteriorly and extends outwards over the anterior end of the esophagus. Nerve ring and cervical papillae 0.15–0.22 mm and 0.18–0.31 mm respectively from head end. Esophagus musculo-glandular, approximately club-shaped, 0.48–0.57 mm long, slightly enlarged at anterior end (60–80 μ in diameter) as well as near posterior end (78 108 μ in diameter), with triradiate lumen, its cuticular lining is continued over the swollen epithelia at the anterior end of the intestine.

Testis tubular, narrow, commencing at a point 0.8–1.1 mm from head end, running backward. Bursa 90 × 130 μ, campanulate, though interrupted anteriorly in median line, divided into a posterior median lobe and two symmetrical lateral lobes; posterior lobe with a slight notch at middle of its free margin, supported by a thick median ray with two widely divergent rami, each of which is tipped with a minute point; lateral lobe subdivided into an anterior lobe supported by a digitiform, basally swollen ray and a posterior lobe supported by a stout, distally enlarged ray with two digitations. The cloacal aperture lies between the two anterior lateral lobes. Spicules equal, 0.13–0.15 mm in length including the attenuated anterior portion which is 24–36 μ long and looks like a handle or a root, the main portion curved ventrally like a chopping knife, distinctly fluted ventrally in the left spicule but dorsally in the right spicule, lateral wings of each spicule membranous and parallel to each other (fig. 33). Gubernaculum placoid, with granular markings, 35–45 × 15–18 μ. No anal papillae.

Female. Body 26–36 × 0.5–0.6 mm, tapering rapidly in esophageal region but gradually toward posterior extremity Nerve ring and cervical papillae



Figs 32–34 *Stenurus glabicephalae* Baylis et Daubney, 1925
Fig 32 Anterior extremity of male, dorsal view
Fig 33 Posterior extremity of male, lateral view
Fig 34 Posterior extremity of female, lateral view

0.18–0.23 mm and 0.25–0.35 mm respectively from head end. Excretory pore not detected. Buccal capsule 14–24 μ in length, 45–60 μ in inside diameter at its anterior end. Esophagus 0.55–0.65 mm long, 80–95 μ broad at its anterior end, 105–132 μ broad at its posterior swelling. Rectum 60–70 μ long, anus ventroterminal. Tail projecting posterodorsad in form of a flat conical prominence, provided with a pair of small papillae at its tip. Ovaries usually commencing some distance behind esophagus, occasionally in esophageal region, running backward alongside each other. In one example the ovary, removed from the body in life, measured 11.7 mm in length with maximum diameter of 0.3 mm at greater middle portion, 30 μ wide at tapering anterior extremity, uniformly wide (70 μ) for a distance of about 1.2 mm at posterior end; receptaculum seminis elliptical, 0.18 mm in diameter; uteri wide, containing embryonated eggs, parallel to each other, joining together near posterior extremity to form a cylindrical ovijector. Latter running straight backward, 0.45–0.75 mm long, lined with flattened epithelia and surrounded by a thick layer of mainly circular muscle fibers. Vagina 0.1–0.15 mm long, lined with cuticle, provided at its greater middle portion with a bulbous sphincter which is 40–50 μ in diameter and consists of outer meridional and inner obliquely circular muscle fibers. Vulva 30–40 μ anteroventral to anus, with two unequal cuticular bosses, which are pressed against each other with the slit-like genital opening between. The anterior boss is 30–33 μ in diameter and contains a papilliform pulp 15–20 μ in diameter, while the posterior is hemispherical and much smaller than the anterior, with or without a small digitiform pulp. Embryos hatching in uterus, 0.32–0.35 mm long and 15–20 μ broad as killed by hot water; tail pointed, 1–6 μ long, slightly flexed. Embryonated eggs 96–120 × 69–78 μ in life, with very thin delicate shell.

LITERATURE

Baylis H. A. and Daubney R. A revision of the lung-worms of cetacea. Parasit, 17, 1925, 206–207.

EXPLANATION OF PLATES

Pl. XLVII.

Figs. 1–3. *Triodontophorus brevicauda* Boulenger, 1916.
Fig. 1. Head end of male with 61 leaf-crown elements, end-on view, 140×.
Fig. 2. Posterior extremity of male, ventral view, 35×.
Fig. 3. Posterior extremity of female, lateral view, 50×.
Figs. 4–6. *Triodontophorus serratus* Looss, 1900.
Fig. 4. Head end of female with 51 leaf-crown elements, end-on view, 200×
Fig. 5. Anterior extremity of female, lateral view, 100×.
Fig. 6. Posterior extremity of male, lateral view, 35×.
Fig. 7–10. *Triodontophorus nipponicus* n. sp.
Fig. 7. Head end of male with 57 leaf-crown elements, end-on view, 200×.
Fig. 8. Anterior extremity of male, subventral view, 35×.
Fig. 9. Posterior extremity of male, lateral view, 75×.
Fig. 10. Posterior extremity of female, lateral view, 35×.

Pl. XLVIII.

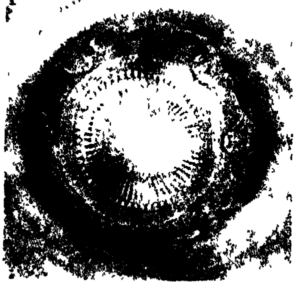
Fig. 11-12. *Trichonema subcoronatum* n. sp.
  Fig. 11. Anterior extremity of male, lateral view, 140×.
  Fig. 12. Posterior extremity of male, lateral view, 35×.
  Fig. 13. Head of female of *Bunostomum trigonocephalum*, lateral view, 75×.
Figs. 14-15. *Syphacia montana* n. sp.
  Fig. 14. Male, lateral view, 50×.
  Fig. 15. Egg, lateral view, 300×.
Figs. 16-18. *Habronema microstoma* (Schneider. 1866)
  Fig. 16. Anterior extremity of female, dorsal view, 100×.
  Fig. 17. Part of female showing posterior ovary and receptaculum seminis, 75×.
  Fig. 18. Posterior extremity of male, ventral view, 35×.
Fig. 19. Posterior extremity of male of *Habronema tyosenense* n. sp., ventral view. 75×.

Pl. XLIX.

  Fig. 20. Posterior extremity of female of *Habronema tyosenense* n. sp., lateral view, 75×.
  Fig. 21. Posterior extremity of male of *Setaria labiatopapillosa* (Alessandrini, 1838), lateral view, 75×.
Figs. 22-28. *Stenurus globicephalae* Baylis et Daubney, 1925.
  Fig. 22. Anterior extremity of male, lateral view, 75×.
  Fig. 23. Posterior extremity of male, ventral view, 75×.
  Fig. 24. Posterior extremity of male, lateral view, 140×.
  Fig. 25. Spicules and gubernaculum pressed under cover glass, 300×.
  Fig. 26. Posterior extremity of female, lateral view, 140×.
  Fig. 27. Eggs, 300×.
  Fig. 28. Embryos, 140×.

ABBREVIATIONS USED IN FIGURES

A	anus
AO	anterior ovary
AP	accessory piece
AU	anterior uterus
B	bursa copulatrix
BB	buccal bristle
BC	buccal capsule
CP	cervical papilla
D	dorsal ray
DC	dentigerous club
DG	dorsal gutter
E	esophagus
EB	embryo
ED	externodorsal ray
EL	externolateral ray
ELC	external leaf-crown
EP	excretory pore
G	gubernaculum
I	intestine
ILC	internal leaf-crown
L	membranous ledge
LA	lateral amphid
LL	lateral lip
LP	lateral papilla
LV	lateroventral ray
M	mouth
ML	mediolateral ray
NR	nerve ring
O	ovary
OJ	ovijector
P	papilla
PH	pharynx
PL	posterolateral ray
PLT	plectane
PO	posterior ovary
PU	posterior uterus
R	rectum
RR	row of chitinous ribs
RS	rosette
SB	spiny band
SM	submedian papilla
SP	spicule
SPH	sphincter
T	testis
TH	tooth
U	uterus
V	vulva
VG	vagina
VV	ventroventral ray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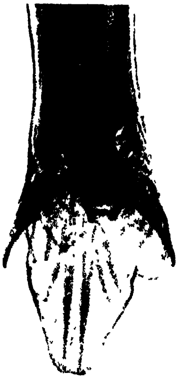
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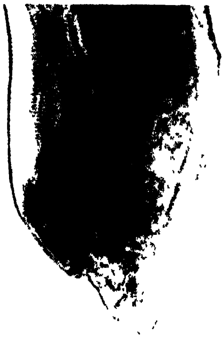
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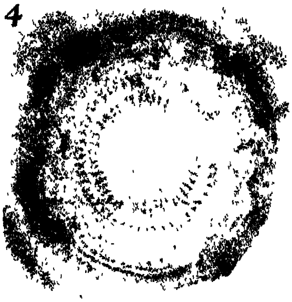
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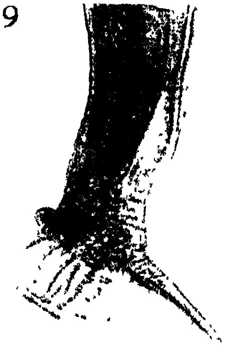
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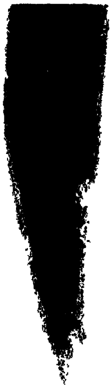
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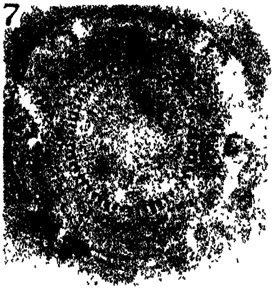
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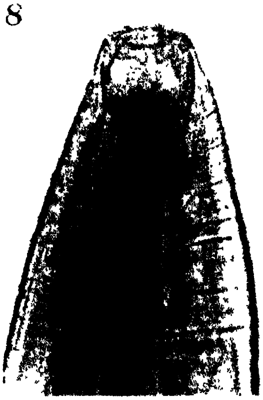
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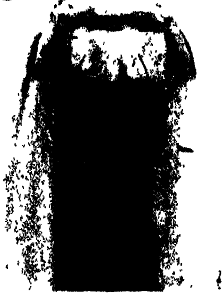
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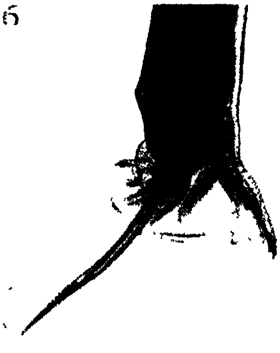
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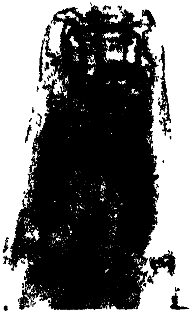

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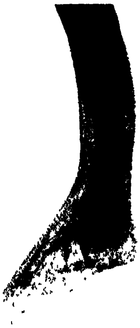

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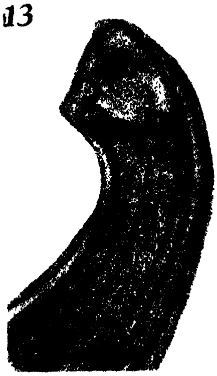

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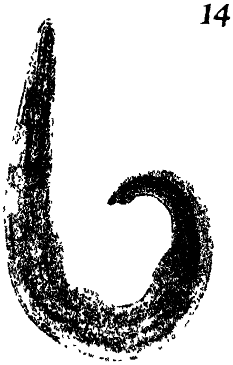

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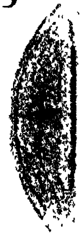

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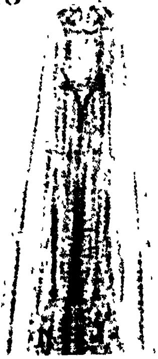

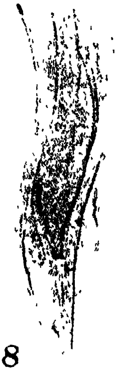

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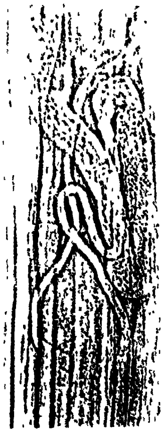

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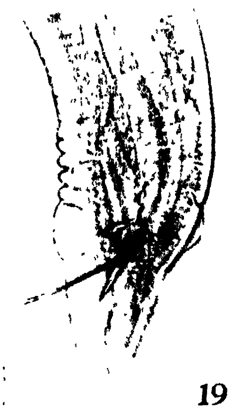

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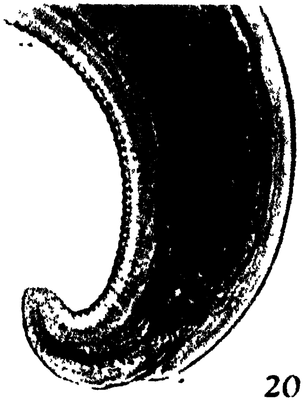

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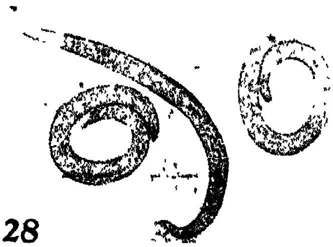

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6. Life History of a Frog Tapeworm *Ophiotaenia ranae* Yamaguti, 1938

By Satyu YAMAGUTI

Laboratory of Parasitology, Kyoto Imperial University

(With 6 Text-figures and Plate L)

In 1931 Lyell J. Thomas worked out the life history of an American frog tapeworm *Ophiotaenia saphena*. He fed the eggs teased out from the adult to *Cyclops vulgaris* var. *brevispinosus*, in which mature procercoids with an invaginated scolex were found 12–14 days after the ingestion of eggs. Direct infection of frogs by accidental eating of infected cyclops was suggested. Three years later the same author succeeded in infecting frog tadpoles by feeding them infected cyclops.

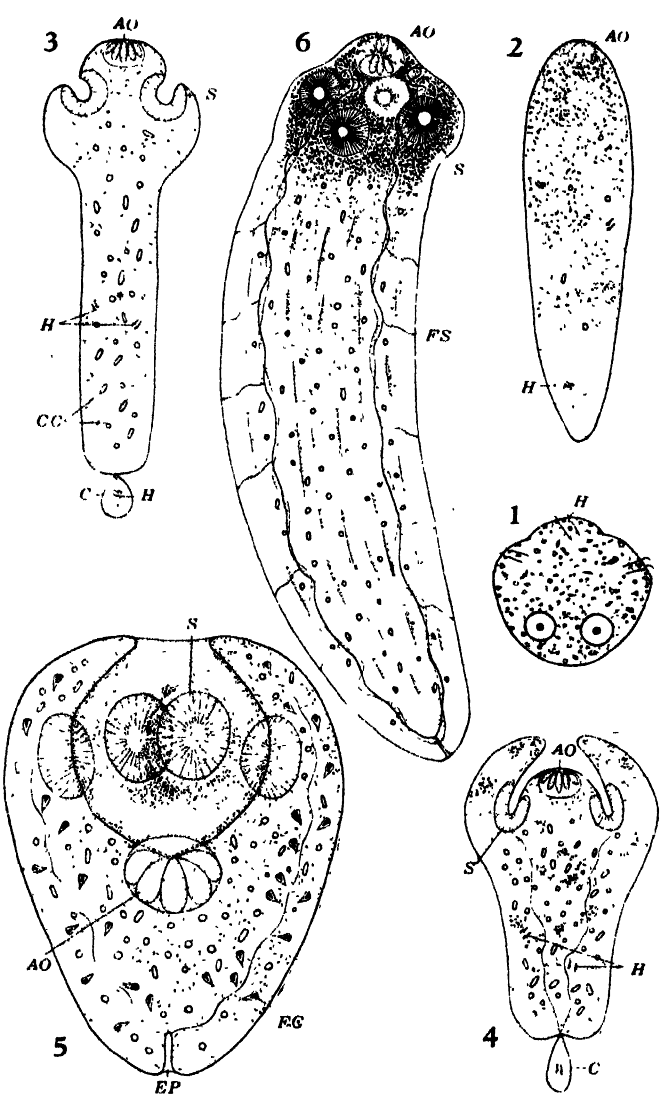
I have recently made an attempt to elucidate the life cycle of a Japanese frog tapeworm *Ophiotaenia ranae*, which was found in *Rana nigromaculata* taken from a pond at Kobata near Kyoto and described in Part 22 of my studies on the helminth fauna of Japan. This species is probably identical with *O. ranarum* Iwata et Matuda, 1938, but the description by these authors being incomplete, I prefer to use the name *Ophiotaenia ranae* mihi for the present.

I. ONCOSPHERE

Text-fig. 1; Pl. L, Figs. 1–2.

The tapeworms when removed from the frog intestine and placed in water shed enormous numbers of eggs (Pl. L. Fig. 1) from the ripe proglottides. The globular outer egg shell, 36–45 μ in diameter, contains transparent aqueous fluid in the comparatively wide space between itself and the embryonic shell. The latter is 21–23 μ in diameter, and contains refractive granules, which shift about with the contraction of the embryo within. The oncospheres are fully developed for infection and measure 12–25 μ in diameter with three pairs of hooks 5 μ long.

When placed (June 6, 1942) in a watch glass containing *Mesocyclops* which had been collected from a natural habitat and examined for parasites with negative results the eggs were promptly eaten by the copepod as easily confirmed by examination under a microscope. The oncospheres, liberated from the egg shell in the midgut of the copepod, remain there for some time contracting and expanding until they make their way into the body cavity of the host. The elapsed time for the penetration varied considerably. The oncospheres which had penetrated into the body cavity shifted from the anterior body region to the posterior or vice versa rolling about passively with the movements of the digestive tract of the host. 24 hours after feeding they are 18–25 μ in diameter in the fresh state, but 15–21 μ in diameter when fixed in acetic sublimate, not showing appreciable growth as compared with the embryo that has just hatched. Near the side opposite the three pairs of the larval hooks are seen two nuclei, each of which is 4–6 μ in diameter, and has a comparatively thick nuclear membrane and a distinct nucleolus. The plasmic contents of the oncosphere are finely granular but appear alveolar when stained in life with neutral red.



Figs. 1–6. Developmental stages of *Ophiotaenia ranae* shown semidiagrammatically.

Fig. 1. oncosphere. Fig. 2. procercoid. Fig. 3. tailed procercoid prior to invagination of head. Fig. 4. tailed cysticercoid. Fig. 5. cysticercoid. Fig. 6. juvenile form. AO apical organ, C cercomer, CC calcareous corpuscle, EP excretory pore, FC flame cell, FS foramen secundum, H larval hook, S sucker.

II. PROCERCOID

Text-figs. 2–3;
Pl. L, Figs. 3–4.

In a week after infection the oncospheres grew up into elongate procercoids in varying degrees of development, some are rather plump and only 30 μ in length, others are up to 0.15 mm long by $30\,\mu$ broad with blunt pointed extremities. In these most advanced forms the first anlage of the apical organ about $20\,\mu$ in diameter has appeared at the extreme anterior end of the body though the four suckers, even their anlagen, are not yet developed; at the posterior extremity is seen a more or less distinct constriction by which the anlage of the cercomer is marked off from the body. The calcareous corpuscles which are not yet recognizable in younger forms have made their first appearance; they are irregular in shape and vary in number from one to several. In addition to these, numerous strongly refractive granules are found in the parenchyma. The three pairs of larval hooks are separated one from another though the two hooks of each pair are close together as before, the posteriormost pair being enclosed in the cercomer as the latter is formed. Flame cells have not yet been observed.

As examined four days later (June 17) the calcareous bodies have increased in number (more than 10), and the rudiments of the suckers have presented themselves on the head, which is now set off from behind by a constriction.

12 days after ingestion of eggs three forms in different degrees of development were observed. The first youngest form which still remains in the first procercoid stage owing to retardation of development or for some other reasons such as delayed infection shows at the head end closely packed cell nuclei a little larger than the others, and at the tail end a rudiment of the cercomer, into which the posterior pair of the hooks has not yet shifted. The second form is characterized by the cercomer and the prominent well-defined head with an apical organ 20 $25\,\mu$ in diameter and four suckers 30 $35\,\mu$ in diameter, as well as by the cylindrical trunk 0.15 mm long and containing large numbers of globular to elliptical calcareous corpuscles 3-$6\,\mu$ in diameter. These corpuscles are scattered throughout the trunk except the scolex and cercomer. In the third form 0.12–0.17 mm long by 0.08 0.11 mm broad and showing the most advanced development, the head end enclosing the apical organ is retracted into the bulbously swollen anterior portion of the trunk, which tapers posteriorly to a blunt point and is provided with a vesicular cercomer. Thus a tailed cysticercoid stage is reached within 12 days.

III. TAILED CYSTICERCOID

Text-fig. 4; Pl. L, Figs. 5–8.

The apical organ, projecting as a hemispherical prominence into the cavity formed by invagination of the anterior portion of the trunk, is $36\,\mu$ long by $42\,\mu$ broad and contains at the apical center about 10 fusiform or elongated elliptical glandular cells arranged radially in a typical rosette. It has a definite limiting membrane separating it from the surrounding parenchyma but no muscular elements characteristic of a sucker. In the circular groove around the retracted head there are four suckers at equal intervals with the compressed apertures directed inwards. From their solely muscular structure it is certain that they are functional suckers. The cuticle is $2\,\mu$ thick and smooth, and the underlying musculature consists mainly of circular fibers. The nuclei of the parenchyma cells are 5–6 μ in diameter, with a thick nuclear membrane and a conspicuous nucleolus. The two pairs of hooks are hardly recognizable in the parenchyma of the trunk, in which the calcareous corpuscles have greatly increased. Another pair lies in the tail vesicle. A pair of rudimentary excretory tubules is seen running sinuously from the head to the point where the cercomer is attached, but flame cells are as yet unable to detect. The cercomer is pyriform and measures 40 μ long by 20 μ broad; its cuticular integument and the underlying muscle layer are thinner than they are in the body proper; the parenchyma appears vesicular and lighter than it is in the trunk, and has no calcareous corpuscles. After fixation in acetic sublimate the nuclei of the tail parenchyma are seen inside the subcuticular muscle layer; they are round, 3.5–4.0 μ in diameter, and possess a thick nuclear membrane and a distinct nucleolus like those of the body parenchyma. Flame cells have not yet been observed. With the shedding of the cercomer the tailed cysticercoid stage proceeds to the tailless cysticercoid stage in about two weeks after infection.

IV. TAILLESS CYSTICERCOID

Text-fig. 5; Pl. L, Figs. 7–9.

The body is approximately pyriform with the broader end in front and measures 0.12–0.18 mm long by 0.09–0.11 mm broad, but when contracted it is subglobular to oval. At the posterior extremity is a more or less distinct notch which is left behind as the cercomer is shed. The cavity becomes deeper than before owing to descent of the apical organ, which is now located at the bottom of the cavity, and the suckers have come to lie anterolateral to the apical organ. The anterior opening of the cavity becomes markedly narrower. In the granular parenchyma are scattered more than 30 calcareous corpuscles of varying shape. The two pairs of larval hooklets are hardly recognizable in the parenchyma. The very fine, tubular, ascending excretory anlage, apparently originating on each side in the posterior part of the body, turns back on itself immediately in front of the two suckers of its own side, and descending as far back as the posterior extremity unites with its fellow to form a short common tubule, which in turn opens to the outside at the terminal notch. The cercomer shed from the body tapers anteriorly to a sharp point, by which it was attached to the body at the terminal notch. Even after it has been detached it is capable of contraction. The parenchyma has not yet undergone vacuolar degeneration, and the paired larval hooks 6 μ long remain unaltered.

V. INFECTION EXPERIMENT

Two weeks old cysticercoids were fed to *Rana nigromaculata*, but with negative results. The culture of the cyclops was continued further on. In the meanwhile, however, the infected copepods died one after another, so that the rest were used for another infection experiment June 23, 17 days after the feeding of eggs. Some of the larval forms found on this day in the body cavity of the infected cyclops were still immature, others, however, were fully developed, showing numerous active flame cells in the parenchyma. The detached cercomers were still alive in the body cavity of the copepod, executing inactive contraction and extension.

One month after the feeding of the infected cyclops one of the three frogs examined harbored a young tapeworm in the small intestine.

VI. JUVENILE FORM

Text-fig 6; Pl. L, Fig. 10.

As fixed in acetic sublimate under a cover glass the young worm is 1.75 mm long by 0.5 mm broad, the apical organ being 0.12 mm and the suckers 0.11 mm in diameter. The cuticle is smooth and 3-5 μ thick. Of the subcuticular muscles the inner longitudinal fibers are fairly well developed. The subcuticular cell layer is thick and compact. The calcareous corpuscles are numerous in the parenchyma. No genital anlagen have been observed. A prolonged observation under cover glass pressure showed that some secretory matter was discharged from the rosette cells of the apical organ, a fact duly suggestive of secretory function of this organ. The ascending excretory tubules of the two sides are continuous posteriorly dorsal to the excretory vesicle, and send out side branches terminating in capillaries; they turn back on themselves by the apical organ to be continued into the descending tubules. The latter give off at irregular intervals numerous short outer branches, which open outside on the lateral margin by so-called foramina secundaria. The excretory vesicle is tubular and lined with a layer of epithelia except at its posterior portion, which is covered with cuticle. There is a ring-shaped anastomosis encircling the base of the apical organ.

The remaining two frogs were examined three months after the feeding, but were negative. In spite of unsatisfactory results of the experiment it is certain that the infection of the final host takes place by eating cyclops infected with mature cysticercoids, and that a second intermediate host is not required.

SUMMARY

1. The eggs taken from the ripe proglottides of the adult contain fully developed oncospheres.

2. When fed to cyclops the eggs are ingested, and the oncospheres are liberated in the midgut and sooner or later make their way into the body cavity of the copepod, where they grow up to infective cysticercoids in more than 17 days after they have passed through two successive stages of development, the procercoid and the tailed cysticercoid.

3. The procercoid stage sets in as the body of the oncosphere becomes

elongated and differentiated into two regions, the head and the trunk. At the head end appears the apical organ earlier than the four suckers. The cercomer is formed at the end of this stage.

4. With the invagination of the head into the anterior part of the trunk the procercoid becomes a tailed cyticercoid. The latter becomes an infective cysticercoid as the cercomer is shed.

5. Of the three pairs of the larval hooklets two remain in the body proper of the procercoid, one is constricted off with the cercomer during the procercoid stage.

6. The cercomer is shed in the body cavity of the copepod at the end of the tailed cysticercoid stage about two weeks after the infection. Even after it has been detached it remains still alive, executing inactive contracting movements.

7. The apical organ or the so-called fifth sucker contains a rosette of glandular cells at its apical center. It is a glandular organ rather than a functional sucker.

8. Calcareous corpuscles are formed in the procercoid stage and gradually increase in number as development proceeds. They are confined to the body proper and lacking in the cercomer.

9. Flame cells make their first appearance in the cysticercoid stage, though the paired primordial excretory tubules are recognizable in the foregoing stage. In the juvenile tapeworm the ascending excretory tubules are united posteriorly, and the descending send out laterally numerous short branches opening outside by "foramina secundaria".

10. *Rana nigromaculata* is infected with the tapeworm by accidental swallowing of cyclops harboring full-grown cysticercoids. No second intermediate hosts are needed.

LITERATURE

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EXPLANATION OF PLATE L

Fig. 1. Egg of *Ophiotaenia ranae*, 300×.
Fig. 2. Oncosphere from body cavity of cyclops, 300×.
Two nuclei are seen on the side opposite the hooklets.
Fig. 3. Earlier procercoid stage, 300×.
Fig. 4. Procercoid with anlage of apical organ, 140×.
Fig. 5. Tailed cysticercoid 200×.
Fig. 6. Same, fixed in acetic sublimate under cover glass pressure, showing apical organ and suckers. 200×.
Fig. 7. Cephalothorax of cyclops harboring tailed and tailless cysticercoids, 75×.
Fig. 8. Tailed and tailless cysticercoids pressed out of infected cyclops, 2 weeks after infection, 75×.
Fig. 9. Mature cysticercoid, 17 days after infection, 140×.
Fig. 10. Juvenile tapeworm from intestine of *Rana nigromaculata*, one month after feeding of 17 days old cysticercoid, 25×.

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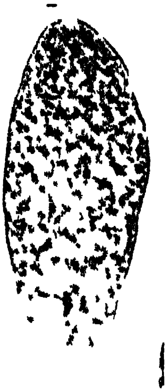

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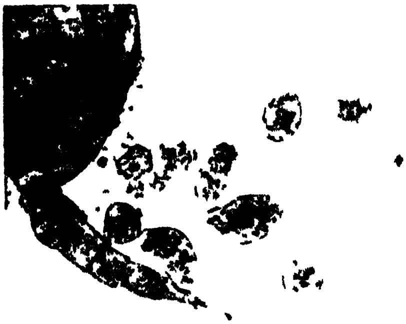

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7. On the Morphology of the Larval Forms of *Paragonimus westermanii*, with Special Reference to their Excretory System

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(With Plate LI LII)

(Received January 1, 1943)

Japanese investigators such as Nakagawa, Ando, Kobayashi, Yoshida, Yokogawa and Wakeshima, etc. have studied the anatomy of the cercaria of the human lung fluke, but their descriptions being inadequate, a re-examination of the worm, especially of its excretory system, is desirable so far as it concerns the hitherto undescribed flame cell pattern. In this respect Ameel, to whom we owe the most complete available description of the cercaria, states that 31 flame cells were counted on each side, though no definite pattern could be determined.

The first intermediate host *Semisulcospira libertina* and the second *Eriocheir japonicus* were collected in an endemic area in Izu Province and placed at my disposal through the kindness of Dr. Yosihiko Kogame of Tokyo, to whom I wish here to express my grateful appreciation.

The cercaria and redia were dissected out of the snail host and examined in life. Unless otherwise stated the measurements were made on the whole mounts subjected to slight cover glass pressure when fixed in acetic sublimate and stained with Heidenhain's hematoxylin. The cysts were taken from the gills and muscles of the crab, and the metacercaria was liberated by rupturing the cyst wall with dissecting needles. It was after many painstaking efforts that intakt worms were set free in this way. In the incubator at a temperature of 38°C the metacercariae emerged from the cysts sooner or later of their own accord, but the flame cells were difficult to count in the examples thus obtained. Fresh solutions of neutral red and Nile blue sulfate gave satisfactory results in staining penetration glands as shown in the photomicrographs (Pl. LII, Figs. 3, 5, 6).

I. REDIA

Pl. LII, Fig. 3.

The mature rediae are plump, ellipsoidal or fusiform, 0.45–1.1 mm long by 0.2–0.4 mm broad in life under slight cover glass pressure, but 0.75–1.3 mm by 0.3–0.4 mm in flattened preparations. They usually contain a small number (not over a dozen) of mature cercariae along with immature ones; at the posterior extremity are massed together a number of developing germ cell balls of varying sizes. The anterior extremity is beset with short hairs hardly recognizable even in the fresh state. There is neither collar nor pediform appendage. The terminal mouth leads immediately into the spherical, muscular pharynx 50–75 μ in diameter. The tubular intestine, more or less constricted at the junction with the pharynx, extends usually beyond the middle of the body, occasionally to the posterior extremity. In immature rediae, however, it is much shorter and confined to the anterior part of the body. The birth pore lies by the side of the pharynx.

The excretory pore opens on each side of the body a little behind the equator; the main collecting tubule proceeds toward the side, on which the intestine is located, and gives rise to an anterior and a posterior branch; the anterior branch runs forward parallel to its fellow of the other side, and divides into four terminal capillaries, of which two are directed forwards and the other backwards, the anteriormost flame cell lying shortly behind the pharynx; the posterior branch also terminates into four capillaries a short distance behind the excretory pore, the posteriormost flame cell lying near the hind end of the body. The flame cell formula is therefore $(4+4)\times 2=16$.

II. CERCARIA

Pl. LI, Fig. 1; Pl. LII, Figs. 4-7.

The fully developed cercaria is approximately elliptical, 0.18–0.26 mm long by 0.07–0.13 mm broad and has a small cylindrical tail 15–30 μ long by 9–17 μ broad. On the ventral side of the hindbody is seen a pronounced median groove, whose wall is made up of a very thick cuticle of the body, and whose maximum depth lies immediately behind the acetabulum with gradual decrease posteriorly. When contracted the groove is distinctly puckered at the margin, but under increased cover glass pressure it is no more recognizable. On the body especially at the anterior extremity there are numerous, very fine hairs at right angles to the surface, with a minute papilliform base. On the lateral edge of the body 10 hairs were counted; the first four and the last two are shorter and closer together than the others, which are set at nearly equal intervals between the neck region and the post-acetabular level. The dorsal and ventral hairs are very short and not recognizable on the hindbody. The cuticle of the body is beset in quincunx with very small spines, that of the tail is however smooth except on the tip, where larger spines are grouped, giving it a shaggy appearance. Elongated subcuticular cystogenous glands are present all over the body but are especially numerous in the neck region.

The oral sucker is 42–63 μ in diameter and opens ventrally at the anterior extremity, with a pair of broad-based papillae on the posterior margin of its aperture. In the dorsal wall is deeply embedded a simple stylet 36 μ long by 9 μ broad and showing several longitudinal striations. There are well developed muscle fibers directed forwards divergently from the base of the stylet as described and figured by Kobayashi. With this stylet the sucker may be produced forwards in form of a cone, executing piercing movements. The prepharynx is slender and 15–33 μ long. The barrel- or pear-shaped pharynx, 10–18 × 8–12 μ, lies slightly nearer to the oral sucker than to the acetabulum. The esophagus and intestine were unable to detect in living worms. They are however recognizable as a very narrow string of cells in well stained whole mounts; the esophagus bifurcates about midway between the pharynx and the acetabulum, and the intestinal limbs extend in a simple arcuate course to the posterior extremity, where they terminate blindly. The acetabulum, 24–36 μ long by 30–38 μ broad, lies behind the middle of the body, with its center dividing the body length in the ratio of 1.4–1.9 : 1.

In front of the acetabulum, partly overlapping this, there are 14 penetration glands with vesicular nuclei. They can be differentiated into two groups not only from their affinities for neutral red or Nile blue sulfate but also from the position and size of the gland cells and the separate course of their ducts. Each outer group consists of 4 large cells containing relatively coarser secretion granules with greater affinities for the above mentioned stains and possessing larger nuclei (6 μ in diameter). The four ducts from this group form a tortuous bundle, which runs forwards near the side of the body and penetrates the oral sucker; the three ducts open close together at the anterodorsal end of the sucker, another duct deviates from the others near its anterior end and proceeding inwards opens a little behind its fellows. Each inner group contains three smaller gland cells with very fine secretion granules staining less intensively than those of the outer cells, and lies in the pre-acetabular median field: the three ducts are bundled like the outer and run up sinuously along the median line near the dorsal surface, and after penetrating the oral sucker open to the outside dorsal to the stylet just medial to the openings of the outer ducts.

The large ganglionic mass is situated on each side of the prepharynx inside the ducts of the outer penetration glands. The genital primordium is present just behind the acetabulum as a transversely elongated mass of cells of irregular outline.

The excretory bladder is 30–60 μ long and lined with a layer of cuboid epithelia. It extends longitudinally in the median field of the hindbody dorsal to the ventral groove mentioned above and opens to the outside by an inverted Y-shaped duct lined with cuticle. The two branches of this duct pass obliquely backward between the body proper and the tail. The collecting tubule, arising at the anterolateral corner of the bladder, proceeds outwards and a little forwards, and is thrown into a glomerular convolution posterolateral to the acetabulum. From this convolution arises an anterior and a posterior secondary collecting tubule. The anterior tubule gives off four branches at intervals and finally divides into three terminal capillaries by the side of the oral sucker. Each of these branches also divides into three capillaries, so that there are 15 capillaries in all for the anterior collecting tubule. A similar branching occurs in the posterior collecting tubule, the last group of capillaries lying at the hind end of the body. The flame cell formula is therefore

$$[(3+3+3+3+3)+(3+3+3+3+)]\times 2=60.$$

III. METACERCARIA

Pl. LI, Fig. 2; Pl. LII, Figs. 8-11.

The mature cyst is globular and has a very thick wall. The outer cyst membrane of the host origin is delicate and transparent, and measures 0.35-0.48 mm by 0.33-0.48 mm when free from pressure. The inner cyst of the parasite origin measures 0.34-0.45 mm by 0.32-0.44 mm in the same condition and has a rigid wall which is 10-21 μ thick and consists of two layers; the outer layer is hyaline, 5-7 μ thick and does not stain with neutral red or Nile blue sulfate, the thicker inner layer staining with neutral red shows very fine lamellar structure. The cyst fluid is aqueous and does not contain any fatty substance or anything alike. When the cysts are kept in an incubator, the excretory waste in the bladder and the epithelia of the wall studded with excretory granules are discharged into the cyst fluid and sooner or later decompose, some of them being swallowed into the intestine. The most conspicuous features of the mature encysted metacercaria are the large median excretory bladder filled with highly refractive excretory granules, the twisted lateral intestinal ceca, and the parenchymatous pigment which gives the worm a pinkish cast recognizable to the naked eye.

The excysted metacercaria is elliptical and measures 0.8-1.1 mm long by 0.27-0.38 mm broad in extended whole mounts. In the living worms the leaf-like edges of the body, especially of the hindbody, turn over ventrally to assume a saucer-like shape. The cuticle is 3 μ thick and beset throughout with minute spines. The outer circular and inner longitudinal subcuticular muscles are distinct, the latter being better developed in the forebody than in the hindbody. The penetration glands have completely disappeared, though their rudiments may occasionally be found over the anterior portion of the intestine. The excystation glands of Ameel are no other than these degenerating penetration glands. I have been unable to detect any other glands not only in the larvae which emerged of their own accord in the incubator, but also in those which were dissected out of the cyst, The subcuticular cells as well as the parenchymatous cells throughout the body contain pinkish pigment granules which can be fixed in absolute alcohol and stain with Lugol's iodine solution or Best's carmine. From these characters it seems certain that the pigment granules are combined with glycogen. Fatty acid is also present in small amount in the above mentioned cells as very fine granules staining dark blue with Nile blue sulfate. In addition, there are scattered throughout the parenchyma numerous refractive globules varying in size from immeasurable smallness to several microns and staining brick red with Sudan III. They are not colored red or a tint between blue and red with Nile blue sulfate.

The stylet is smaller than it was in the cercarial stage, measuring 21-28 μ in length. The oral sucker, pharynx and acetabulum are well developed and muscular, and measure 65-80 × 90-100 μ, 36-50 × 45-60 μ and 115-140 × 117-147 μ respectively. The acetabulum lies usually a little in front of the middle of the body; its center divides the body length in the ratio of 1 : 1-1.5. The prepharynx which was considerably long in the preceding stage is now very short or practically lacking. The esophagus is 35–60 μ long and has a cuticular lining and a distinct layer of circular muscle fibers. The intestinal ceca are usually narrow at the anterior portion but broad and voluminous for the most part, each describing three to four (occasionally more) spiral turns and terminating at the posterior extremity. Except at the very beginning lined with cuticle they are covered inside with a layer of epithelia and outside with a coat of inner circular and outer longitudinal muscle fibers. The aqueous intestinal content is colored dark blue with Nile blue sulfate, violet red with neutral red, but not with Sudan III. In immature metacercariae there are mixed apparently cellular elements and their debris. In mature metacercariae however minute acicular crystals are seen instead.

The ganglionic mass with anterior and posterior rami lies posterolateral to the pharynx, with the transverse commissure dorsal to the anterior end of the esophagus. In contracted examples it may be on a level with the pharynx.

The primordia of the reproductive organs are well recognizable in stained preparations. The testes are represented by small compact masses lying symmetrically just lateral to the excretory vesicle at about the junction of the middle with the posterior third of the body. The primordia of the ovarial complex and terminal genitalia lie just behind the acetabulum. Clusters of spherical vacuolate bodies as observed by Ameel in the American lung fluke are recognizable along the sides of the body not only in the hindbody but also in the forebody. They are undoubtedly the anlage of the vitellaria.

The excretory bladder is a large elongated saccular organ with a rounded anterior end and filling up almost the entire intercecal field between the intestinal bifurcation and the posterior extremity. It is provided throughout its length with longitudinal muscle fibers and lined with a layer of epithelia except at the funnel-shaped terminal portion. The latter is covered with thick cuticle with rough, apparently villoid surface, and surrounded by glandular accompanying cells. It opens to the exterior on the dorsal surface close to the posterior extremity. In the fresh examples dissected out of the cyst the bladder is distended with isolated excretory granules and large, oval or rounded, desquamated epithelia filled with excretory granules. In the worms that have emerged from the cyst of their own accord, however, the excretory bladder is reduced to a simple tube passing exactly dorsal to the acetabulum and tapering anteriorly, and contains more elongate, desquamated epithelia; epithelial villi of various lengths may be observed projecting into the lumen of the bladder. The primary collecting tubule leaving each side of the vesicle just behind the acetabulum runs outward and becomes convoluted ventral, medial or lateral to the intestinal limb, where it gives rise to an anterior and a posterior secondary collecting tubule. The anterior tubule ascends sinuously along the intestine toward the anterior extremity, giving off four tertiary collecting tubules at some intervals, and finally divides in the neck region into three capillaries, one of which terminates by the side of the oral sucker, the others terminate dorsal and ventral to the sucker respectively. The tertiary collecting tubules are comparatively short and split up each into three terminal capillaries, the posteriormost group of the capillaries being on a level with the acetabulum. In the forebody therefore there are on each side five groups of three flame cells each. In the hindbody the posterior collecting tubule descends in the extracecal field, sending out four tertiary tubules, and finally branches into three terminal capillaries, the posteriormost flame cell lying at the cecal end. Though not shown differently in the figure one capillary of each group lies dorsally, another ventrally, and the remaining laterally. The flame cell formula agrees completely with that of the cercaria.

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EXPLANATION OF PLATES

Plate LI.

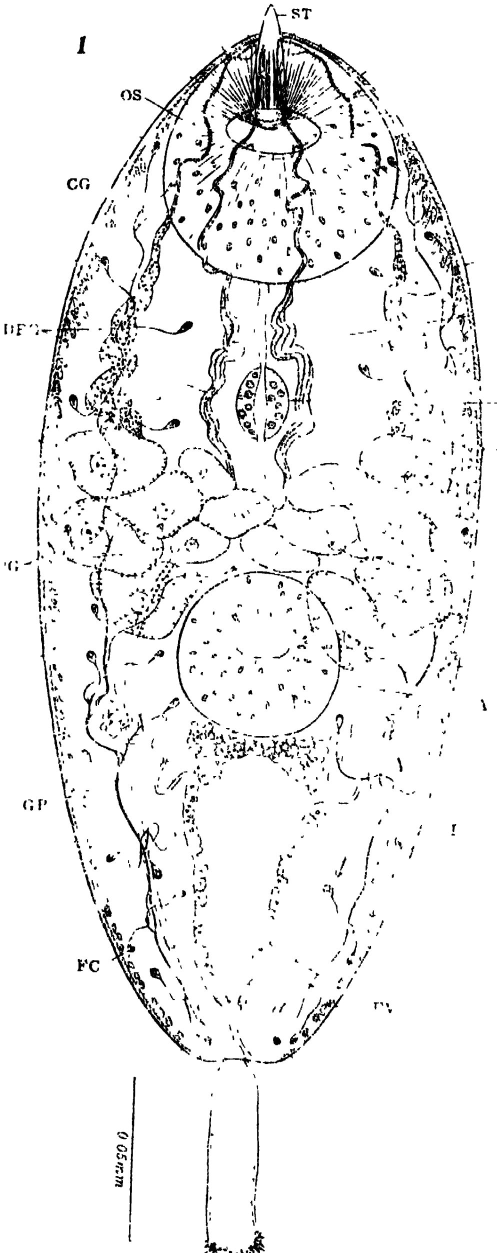
Fig. 1. Mature cercaria of *Paragonimus westermanii*.
Fig. 2. Mature metacercaria of *Paragonimus westermanii*.

Plate LII.

Fig. 3. Redia containing two mature cercariae, 35×. Intestine of redia and penetration glands of cercaria stained with neutral red.
Fig. 4. Mature cercaria, ventral view, 140×.
Fig. 5. Mature cercaria, ventral view, 140×. Ganglionic mass and penetration glands stained with Nile blue sulfate.
Fig. 6. Mature cercaria, ventrolateral view, 140×. Penetration glands stained with Nile blue sulfate. Ventral median groove of hindbody indicated.
Fig. 7. Mature cercaria fixed in acetic sublimate, stained with Heidenhain's hematoxylin and mounted in balsam, ventral view, 200×.
Fig. 8. Cyst containing mature metacercaria, 75×.
Fig. 9. Mature metacercaria liberated from cyst, ventral view, 75×. Intestine stained with Nile blue sulfate. Excretory vesicle distended with excretory granules.
Fig. 10. Mature metacercaria which emerged in the incubator at 38°C, stained with neutral red, ventral view, 75×.
Fig. 11. Same, fixed in formol and stained with Sudan III, ventral view, 75×.

ABBREVIATIONS USED IN FIGURES

A	Acetabulum
CG	cystogenous cell
DPG	ducts of penetration glands
EP	excretory pore
EV	excretory vesicle
FC	flame cell
G	ganglionic mass
GP	genital primordia
I	intestine
OS	oral sucker
P	pharynx
PG	penetration gland
ST	stylet
T	testis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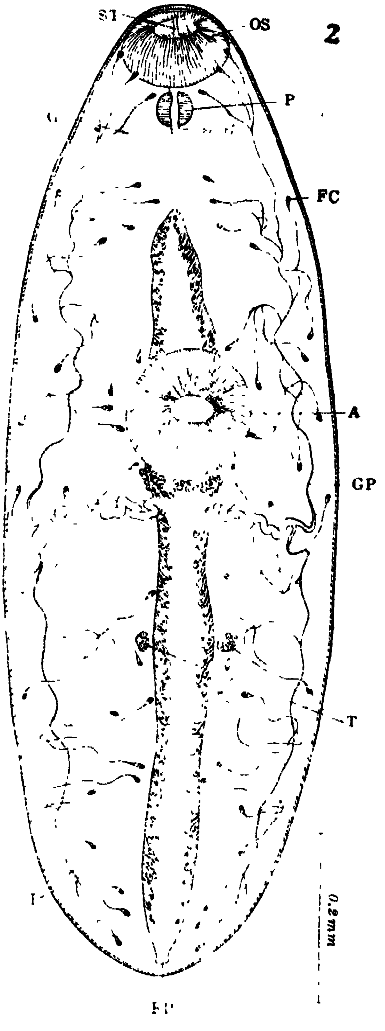
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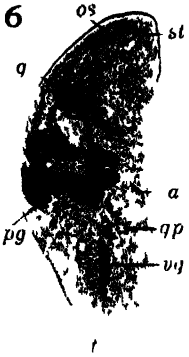

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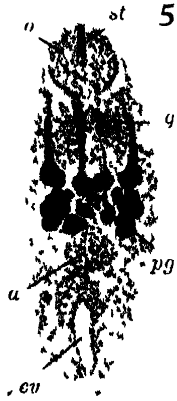

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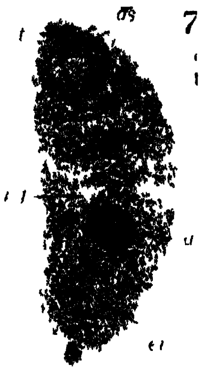

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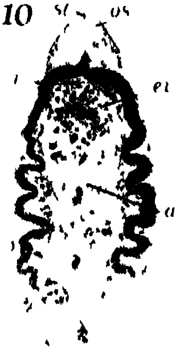

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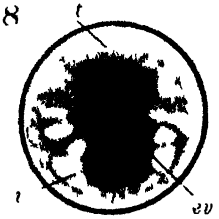

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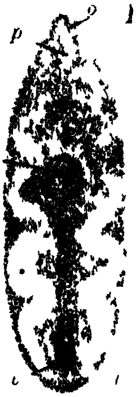

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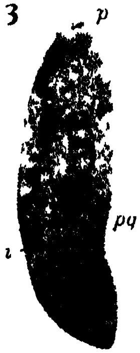

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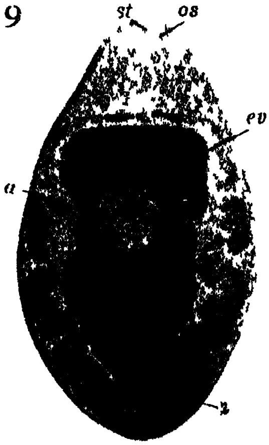

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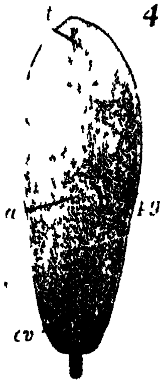

8. Disturbances Initiated from Naked Surface of Muscle Protoplasm

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(With 14 Tables, 3 Text-Figures and Plates LIII–LIV)

(Received January 11, 1943)

The experiments given below were made mainly, unless otherwise stated, with single fibres isolated from biceps muscles of the frog (*Rana japonica*). The single fibres were dissected out under a binocular microscope with a special care not to give a slightest impairment to any part of the fibre from one end to the other. The isolated fibre was placed in a small glass vessel filled with Ringer's solution (0.12 M NaCl, 0.002 M KCl, 0.0013 M $CaCl_2$, pH = 7.1~7.2 by Na-phosphate with P = 6 mgm%) and clamped at the tendons attached to the ends of the fibre. Then the Ringer's solution surrounding the fibre was replaced by M/12 $CaCl_2$. If some impairment had been given to the fibre, though barely visible it may be under high magnification, a local turbidity and a local contraction of the protoplasm occurred around the injury by a several minutes immersion of the muscle in M/12 $CaCl_2$. The fibre which was considered non-injured by this means, was washed thoroughly with Ringer's solution and then subjected to various kinds of examinations. Even in fibres, which appeared quite sound with regard to the microscopic appearances (i. e. cross-striae, protoplasmic transparency etc.), injuries could sometimes be detected by this treatment.

As a control, some attempts were made to use the fibre of the fairly normal appearance without the initial Ca-treatment, and it was found that the fibres which were proved non-injured by a subsequent immersion in M/12 $CaCl_2$, gave results quite identical with those obtained with the fibres ascertained to be non-injured by the initial Ca-treatment. Hence it may be safely mentioned that an immersion of the fibre in M/12 $CaCl_2$ gives practically no after-effect, if the fibre is prepared without mechanical injuries.

The fibre in a narrow muscle chamber was clamped at the tendon at one end of the fibre, while the tendon at the other end was connected with a micro-isometric (sometimes a micro-auxotonic) lever of a period of 26 (sometimes 18) milliseconds, by which the tension developed in the fibre could be registered optically on sliding photographic plates. On the other hand, a number of fine granules (carmine, carbon black or carborandum) were adhered on the surface of the fibre so as to form a series of dark spots on the contour line of the fibre in the lateral view. The image of these granules, not inclusive of that of the contour line of the fibre, was focused sharply, through a very narrow slit and after an appropriate magnification, on the same photographic plate, so that both the total tension developed by the fibre and the local movement of the fibre protoplasm could be recorded simultaneously (cf. Plate-figures). The absolute value of the tension developed was known by an appropriate calibration performed separately with the same arrangement.

In the case of contraction too slow to be registered conveniently by the sliding camera, the reaction of the fibre was recorded on cinemato-micrographic films (film: U. S. Panchro "Sakura" 16 mm, camera: Siemens Type C). In this case the development of tension of the fibre could be measured in terms of the movement of the auxotonic lever which was calibrated by a previous stretching of the fibre under known tension.

During the application of test solutions to the fibre or during the recovery of the fibre in Ringer's solution, the solution was made to flow constantly through the narrow muscle chamber from one end to the other, the over-flow being prevented by means of a strong suction-pipette used as the outlet device and operated by a pump. Tests with coloured solution (neutral red) indicated that the muscle chamber was of a proper shape and size so as to allow a complete replacement of the solution surrounding the fibre in a fairly short time. The frequent change of the running solution from one to the other was practised by a suitable modification in connection with the reservoir of solution, which could easily be managed by a 6-way stop-cock specially deviced for this purpose. Since in this chamber, as is mentioned above, the solution came first to one end of the fibre and last to the opposite, the effect of the replaced solution was in no way exactly synchronous over the entire length of the fibre (cf. Plate-figures), although the replacement of the solution was accomplished rather quick. However, if, in order to make the effect synchronous, the axis of the fibre was placed perpendicular to the direction of the stream of solution, the photographic registration of the granules became impossible, since the fibre was bent slightly in an unsettled way owing to the dashing effect of the running solution. From this technical reason, the solution had to be applied to the fibre by a stream running parallel to the axis of the fibre, so far as the photographic registration of the granules was required.

Stimulation of single muscle fibre with K-ions

There are some authors who maintain that the isolated single fibre of frog skeletal muscle shows no response to KCl, although the muscle tissue as a whole undergoes a rapid transient contracture on transfer to K-rich solution (Graham and Sichel 1939). Such a difference existing between the whole muscle and its element is rather difficult to understand. As a matter of fact, at least in the present material, the single fibre, isolated free from injury, does show a long sustained contraction (contracture), when the surrounding Ringer's solution is replaced by M/8 KCl (pH 7.2 by $KHCO_3$) as will be seen in Plate-figures. Continued immersion in M/8 KCl solution abolishes the contraction completely within some fraction of a minute, and the fibre resumes its original resting length in this stimulant solution. In this state, replacement of M/8

KCl with M/16 K-citrate has no effect at all and the fibre is perfectly insensitive to electric current. However, in such a non-irritable state, the muscle protoplasm is still capable of reacting with contraction, if suitable substances (e. g. Ca-ions) are injected, by a micro-pipette, within the fibre, or if the muscle is put in distilled water. These results seem to have some connection with the findings of Ashkenaz (1938 p. 144) that the muscle fibre placed in isosmotic KCl, though no more sensitive to electric current, does respond to irradiation with mercury vapour lamp.

On return to Ringer's solution, the K-poisoned fibre shows no visible reaction, but after being allowed to stand in Ringer's solution for a few minutes, the fibre restores its capacity to respond again with a contraction quite identical with the previous ones when M/8 KCl is readmitted on the surface of the fibre. Hence, it may be stated that the effect of K-ions is perfectly reversible. The stimulation with K-ions and its recovery in Ringer's solution can be repeated without any sign of fatigue for several hours, if the preparation is made perfectly free from injuries and, after each K-stimulation, the fibre is allowed to have enough time to complete the recovery in Ringer's solution. If, however, the recovery in Ringer's solution is not complete, or if the fibre is injured in some way or other, the repeated series of contractions are by no means uniform; with repetition of stimulations the height of contracture becomes reduced, the rate of contracture becomes slower and the time required for the commencement of contracture becomes prolonged. It must be mentioned that, contrary to the result obtained by Graham and Sichel (1939), even in the K-poisoned state, an immersion in M/12 $CaCl_2$ gives no detectable effect on the fibre so long as the fibre remains uninjured.

In freshly prepared fibres, when M/8 KCl is applied, a train of rapid twitchings can often be demonstrated before the onset of the slow sustained contraction (Pl. LIII, Fig. II). However, these initial twitchings disappear after a short series of K-stimulation and its recovery in Ringer's solution. In fact, in preparations slightly injured or in somewhat fatigued fibres, only the sustained contraction is obtained from the beginning. This initial twitchings are not specific to the single fibre preparation, and they are also demonstrable in the K-contracture of the muscle tissue as a whole, if the tissue is fresh and free from mechanical injuries. Even in those preparations of muscle tissue, in which the initial twitchings are associated at first, only the usual type of K-contracture is established after repetitive stimulations with K-ions or after an artificial injury being given to the tissue.

Tests with one and the same fibre reveals that the type of contracture induced by M/8 KCl is not very much different from that caused by M/16 K-citrate, although the initial twitchings take place much more markedly with K-citrate than with KCl. However, the situation is somewhat different with Na-ions. The fibre shows a slow sustained contraction in M/16 Na-citrate but in M/8 NaCl (pH 7.2 by $NaHCO_3$) a rapid series of rhythmic twitchings lasts for a short time.

Electrical stimulation and K-contracture

Many investigators (cf. Ramsey and Street 1938) have mentioned that in the isolated single muscle fibres the response to electrical stimulation is not of the all-or-none type, and this can be confirmed also in the present material.

In an earlier part of the present experiment electrical stimulation was given to the fibre through a pair of long Ag-AgCl electrodes lying parallel to the longitudinal axis of the fibre, with a view to stimulating the entire length of the fibre simultaneously by the transverse current, as Brown and Sichel (1936) have suggested. However, by the analysis of the movement of the granules adhereing on the surface of the fibre, it was revealed that, even with the supermaximal strength of stimulation, the contraction is not strictly synchronous over the entire length of the fibre; i. e., in the fibre fixed on the isometric lever, the region excited earlier does shorten locally by stretching some other not yet excited parts of the fibre, while with the progress of time, the latter shortens by pulling back the former to some extent (Pl. LIII, Fig. I). Consequently even with a strictly isometric arrangement, in which the total length of the fibre is kept unaltered during the contraction, it is rather impossible to get a contraction which is really "isometric" with respect to the elementary parts of muscle substance. It may be considered that, at least in the present material, the excitability, and hence the reaction time, is not uniform on the entire length of the fibre. On this account probably, in spite of some theoretical expectation offered by Brown and Sichel (1936), there could be obtained no such a definite relation that the transverse stimulation over the entire length of the fibre produces the maximal contraction always exceeding that obtained either by the longitudinal stimulation of the fibre or by the localized stimulation with transverse current which can be given by the combination of a small cathode and a large anode lying parallel to the fibre. However, in the present experiment, the large parallel electrodes were employed, unless otherwise stated, without special reasons.

The height of twitch evoked by a single supermaximal induction shock is by far smaller than the height of contracture caused by M/8 KCl (Pl. LIII, Figs. I and II). Even in a completely fused tetanic contraction produced by a supermaximal induction shocks, the height of contraction is still less than that caused by M/8 KCl. This is contrary to the case obtained with the muscle tissue as a whole, in which the height of contraction induced by a maximal induction shock is, as has been pointed out by some authors (cf. Gasser 1930 p. 52), very much greater than that obtained by M/8 KCl. However, this discrepancy may simply be due to the situation that, in the muscle tissue as a whole, the multifibre summation is more or less synchronous in the case of electrical stimulation, while the commencement of contraction due to K-stimulation must be different for different fibres, depending largely on the distance of the individual fibres from the surface of the tissue at which the K-solution is applied, and that, in single muscle fibres, no such statistical complication takes place with respect to the time course of events. It may be remarked that the contraction is not the same, at least quantitatively, with electrical stimulation as with K-stimulation, and in this sense again the response of muscle fibre may be said to be not of all-or-none type.

However, with respect to the excitability of the fibre, there is a clear correlation between electrical stimulation and K-stimulation. If a supermaximal induction shock is given to the muscle fibre at various stages of K-contracture, it is found that the response to the electric test shock becomes less with the advance of K-contracture and disappears during the later half of the rising phase of contracture. In this series of experiments the electric current was sent in the longitudinal direction of the fibre and the KCl solution was applied to the fibre as a constant stream passing in the direction opposite to the electric current. It is therefore conceivable that at the cathode side of the preparation, at which the fibre is excited by the current, the K-contracture would be established, and come to an end as well, by some time earlier than the rest of the fibre. This may probably be the reason why the electric shock has lost its effect before the rising phase of K-contracture is over. It may be said from this, that, together with the responsiveness of the muscle to K-ions, the excitability for electric current is also abolished by the poisoning effect of K-ions.

On return to Ringer's solution, the K-poisoned muscle shows the first sign of electric excitability within half a minute, and then the height of contraction due to electric stimuli increases gradually until the original responsiveness is restored in a few minutes. Prior to the restoration of the original state, there is seen a supernormal period, in which the electric stimulus produces a contraction more than 150 per cent of the normal value. Tests with one and the same preparation indicate that, except for this supernormal phase, there is a good parallelism between electrical stimulation and K-stimulation in the time course of recovery after the K-poisoning.

If an injured fibre is used, or if the recovery is not complete after K-stimulation, there appears, as is mentioned above, a decay in response in successive stimulations with K-ions, which is accompanied also with an analogous decay in the response for electric stimulation.

From these facts, it may be suggested that, although the magnitude of response is not the same with electric stimuli as with K-ions, yet the stimulation mechanism seems to involve some process common to both stimulants.

All-or-none principle in K-stimulation

An attempt is made to cut off the K-stimulation at various intervals measured from the beginning of stimulation. The following data are one of the results obtained (at 13.5°C, arrows: the sequence of measurement).

Stimulation time in sec.	3 →	6 →	9 →	12 →	15 →	20 →	9 →	6 →	3
Height of K-contacture in arbitrary unit	1.9	9.5	14.0	16.9	16.8	16.9	13.9	9.2	1.8

It will be clear from this, that, if the time of application of K-solutions be shorter than a certain limiting value (12 sec. in this case), the resulting contraction becomes progressively smaller in height (and also in duration) with reduction of the stimulation time. Thus, the amount of what is evoked in muscle fibre by K-ions, is considered to depend on the quantity of K-ions given to the muscle as stimulant, and in this sense it may be said that the K-contracture is not of the all-or-none nature. With muscle tissue as a whole, it is rather difficult to analyse such a relationship, owing to the statistical complications of the time required for K-ions to reach individual contractile elements.

The following data may serve also as a proof for the invalidity of the all-or-none principle, in that the contraction height is progressively diminished as the applied K-solution is diluted with the isotonic $CaCl_2$ solution.

Volume ratio (M/8 KCl:M/12 $CaCl_2$)	1:0	7:1	3:1	1:1	1:3	0:1
Height of K-contracture in relative value (16.0°C)	100	90	75	34	2	0

K-stimulation in injured fibres

If, under the microscope, an artificial injury (e. g. a pinching with minute points of forceps) is given near one end of the muscle fibre which has been prepared without injury and kept quietly in Ringer's solution, a sort of coagulum is seen to form within the sarcolemma at the site of injury and increases very slowly to cover the entire length of the fibre. The coagulum is deprived of the normal cross-striation, so that, besides its darker appearances, it is easily distinguished from the adjacent part of the fibre.

The coagulum does not respond to K-ions, while the uninjured part of the fibre contracts, if M/8 KCl is applied within a certain limit of time after the injury is made. However, in the lapse of time, the contraction of the fibre caused by K-ions as well as by electrical shocks becomes weaker, and finally these agents fail to stimulate the fibre, although all the microscopic appearances of the fibre (e. g. cross-striae, transparency etc.) remain still fairly normal, except for the region at which the coagulum has been formed. This effect of injury is quite the same as with the biceps muscle as a whole.

If, in the injured fibre placed in Ringer's solution, the time decrease of the responsiveness to K-ions is examined by making use of the granule method above described, it can be observed that the region of the fibre proximal to the injured end becomes non-irritable earlier, while the distal part of the fibre is still capable of responding to K-ions quite normally (Pl. LIV, Figs. III and IV). The non-irritable region spreads with time from the injured end to the other, and the spreading velocity is relatively quick at first and then slowed down gradually. Since the fraction of the fibre excitable with K-ions becomes less with the advance of time, it is natural that the magnitude of K-contracture of the total fibre is a function of time after the injury being made.

It may therefore be considered that a sort of "insensibilization wave" is started from the injured spot to be propagated along the entire length of the fibre and the part of the fibre at which the wave has arrived, can respond neither to K-ions nor to electric shocks. As is mentioned above, the modification of the muscle structure brought about by the wave is by no means detectable under the highest magnification. The tension-length relation of the fibre (Fig. 1) reveals that the elastic properties of the muscle substance do not seem to be altered after the wave has swept over the fibre.

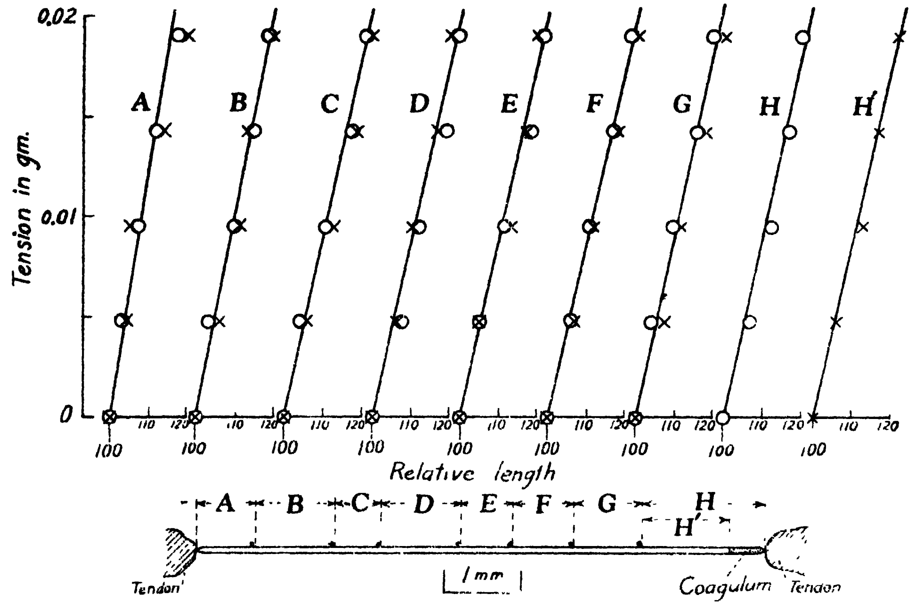

Fig. 1. Tension-length relation in elementary parts of muscle fibre

The non-injured single muscle fibre (biceps), placed in Ringer's solution at 27.0°C, was stretched under known values of tension, and the distances of carmine granules adhering on the surface of the fibre (A, B, C, D, E, F, G and H in the lower diagram) were measured from the photographic records to construct the curves representing the tension-length relation in these elementary parts of muscle fibre (circular marks in the upper figure). The relative length is given in terms of the percentage of the resting unloaded length of each part of the fibre.

Then an injury was given at one end of the fibre with the points of forceps. After it was ascertained, by occassional stimulations with M/8 KCl, that the insensibilization wave from the injury had swept over the entire length of the fibre (it took about 10 min. in this case), the determination of the elastic modulus was repeated as before with respect to the elementary parts of the fibre, the results being plotted in the upper figure by cross marks. In this case, on account of the formation of coagulum of a length (H--H'), the part H could not be tested, and the measurement had to be done with the part H', instead of H. In all of these determinations, the velocity of stretching was rather high (about 10 per cent stretching in 1.5~2.0 sec.) and the length of the parts of fibre was recorded photographically during the stretching, together with the tension indicated by the micro-auxotonic lever, with the aid of sliding camera.

It will be confirmed from this figure, that the elastic modulus is practically uniform over the entire length of the fibre, and also that the insensibilization wave does not modify the elastic properties of muscle protoplasm.

An immersion of the insensibilized fibre in M/12 $CaCl_2$ for a short time (e. g. 3 min. at 19°C) makes the insensibilized fraction of the fibre responsive to K-ions once more, though the coagulum increases markedly by this treatment. Thus it is considered that the effect of the wave is reversible at least partly.

The velocity of propagation of the wave is rather slow. An injury given by pinching the fibre with forceps sends out the wave at a rate of about 1/15 cm per min. at 14–15°C (or of about 1/4 cm per min. at 24-25°C) in the proximal (to the injury) part of the fibre placed in Ringer's solution. However, this is by far faster than the spreading of the coagulum initiated also from the injured site under the same condition (as to the latter, description will be given below). Up to a certain limit, an injury of greater area tends to send out the wave at a higher velocity; an injury extending to a column of fibre of about 1 mm in length (produced by pinching with minute points of forceps) sends out the wave at about a rate given above, but from such a small injury as is restricted to one side of the fibre and barely detectable after the Ca-treatment, the wave is started at a very much slower rate. However, in the case of injury as large as to cover the entire cross-section of the fibre or more, the velocity of the wave seems independent of the size of the injury.

Some authors maintain that the isolated single fibres of frog skeletal muscle are, contrary to the case with the whole intact muscle, insensitive to electrical stimulation (Chambers and Hale 1932) and to K-stimulation (Graham and Sichel 1939). However, in view of the above results, it may be considered that the preparation they used might have some injury (probably the fibre having been cut at the ends), from where the insensibilization wave had swept all over the fibre before their tests were made.

If a fibre, over which the wave has passed, is injected, by a micro-pipette, with suitable substances (e. g. Ca-solution), the protoplasm can still shorten apparently in the normal way. This may suggest that the wave affects the muscle only to abolish the establishment of some earlier parts of the excitation processes, leaving the contractile mechanism of the protoplasm more or less in the normal state. In this connection it is interesting to recall the fact that when a muscle is fatigued out by successive stimnlations with direct current, its original active condition can be restored by changing the direction of stimulating current and so the fatigue in this case (cathodal fatigue) can scarcely be taken as an exhaustion of the source of the contractile energy (Guláscy 1930). In the present case the actual happenings may be that the injury current of the fibre, established between the coagulum and the intact region, flows through the cell membrane of the intact region in the direction from within to without, so that the membrane is placed continually under the cathelectrotonic effect of the current and the fatigue in the sense of Guláscy (loc. cit.) may be induced in this region. In other words, it may be suggested that the loss of irritability brought about by the insensibilization wave is an electric polar fatigue usually observed at the cathodal membrane, since there must exist an injury current in the injured fibre, by which the cathodal fatigue must be established in the intact region. Since, to complete the cathodal fatigue, a longer time would be required with a smaller injury current and the current would be the smaller, the longer is the distance from the injured site, it is natural that the part of intact region proximal to the injury becomes insensibilized earlier than the distal part. This may be why the insensibilization appears to begin at the injured spot to spread over the entire length of the fibre as if in a form of "wave". The fact that the spreading velocity of the wave is slow in the case of barely detectable injury, may well find its explanation in the weak injury current produced in such a case.

The hypothesis presented here seems to be supported by 3 lines of evidence given below.

1) The fibre placed in Ringer's solution was injured at one end with points of forceps and a continuous current was sent immediately in the direction from the intact side to the injured end, in order to antagonize the injury current in most parts of the intact cell surface. The non-polarizable electrodes employed in this series of experiments were of the type of Ag-AgCl in saturated NaCl, which were connected to the muscle chamber by agar bridges made up with Ringer's solution, and the current intensity (usually of about twice the normal rheobasic value) was kept carefully constant throughout the experiment. As a control, another fibre, obtained from the same frog and roughly of the same natural length, was tested in the same way except for the passage of the electric current. It was found that without the electric current the insensibilization wave was propagated over the entire length of the fibre within 6~15 min., but with the electric current the excitability of the fibre to K-ions was not entirely abolished even after 40 min. Thus it is clear that the antagonizing current given to the intact region of the fibre can retard the spreading of the insensibilization wave. By making use of the granule method, it was shown that, if the current was increased suddenly during the experiment, the boundary line between the intact part and the insensibilized area was shifted towards the injured side, thus the insensibilized area being decreased as a consequence of sudden rise in the current intensity. Even after the insensibilization wave had swept over the entire length of the fibre, if the electric current was passed subsequently in the direction to make the injured end cathodic, the fibre recovered its sensitiveness to K-ions partly again and this recovered region was the larger, the stronger was the current. It may therefore be remarked that the anelectrotonic effect given to the cell membrane is of such a nature as to antagonize the insensibilization not only during its establishment but also after its being completed. If, on the other hand, the current was sent in the reversed direction, the entire length of the fibre became insensitive to K-ions in a short time, and with the current passing in this direction no recovery could be induced in the once insensibilized fibre.

2) The intact fibre, ascertained to be non-injured by the Ca-treatment, was subjected to a continuous electric current passing from one end of the fibre to the other. By applying M/8 KCl to the fibre from time to time, it was found that the K-contracture became progressively smaller with time, but this decay of response was established at a rather slow rate in comparison

with that observed in the case of injured fibre in which the current was sent from the intact to the injured end. The granule method revealed that this depression in contraction was due to an increase with time of the insensibilized area spreading from the cathodal tip, and that, if the current was strengthened suddenly, the insensibilized area was decreased temporarily as a consequence. On cutting off the current, it was shown (by subsequent occasional stimulations with K-ions) that, in the fibre, no recovery to the original excitability took place within several minutes or rather the response was diminished further with time, although any sign of mechanical injury could be detected nowhere on the fibre even with the Ca-method. This may probably be ascribed to the situation that, after the cessation of the electric current, the entire surface of the fibre may not immediately be made equi-potential, so that a local current passing in the protoplasm in the direction opposite to that of the applied current may be established to increase further the insensibilized area, in spite of there being no mechanical injury on the fibre. Reversal of the direction of the applied current could not enhance the once reduced responsiveness of the fibre to K-ions. It may be said from these facts, that the insensibilization of the fibre, probably of the same nature as that observed in the injured muscle, can be induced without mechanical injury, if an electric current is led through the fibre from an external source.

3) In this series of experiments, the narrow muscle chamber above described was modified so as to be divided into three compartments arranged in series, each narrow end compartment being connected with the small middle one by a minute perforation made through the septum wall. Passing freely through these minute pores, the isolated non-injured single fibre was placed longitudinally over the entire length of the narrow muscle chamber, one of the tendons being clamped in one end compartment and the other tendon in the other end compartment. In this case care was taken not to allow the fibre any mechanical contact with the septum walls at the pores. The solution to be applied was discharged continually in one of the end compartments and allowed to flow, through the minute pore, into the middle compartment, where it joined with other solution coming similarly from the other end compartment so as to be led into a side compartment through another minute pore and then pumped out by a strong suction-pipette.

By making use of the coloration of neutral red solution, it was confirmed that the solution streaming through the end compartment could be replaced completely by a flow of another solution in a fairly short time, and that, if the velocity of the solution flowing through the pore between the end compartment and the middle one was adjusted appropriately, the solution within the end compartment was practically independent of the solution used in the other end compartment. Thus, without any aid of cementing substance like vaseline (which was found usually to initiate the insensibilization wave in the fibre), it was possible to immerse a required fraction of the fibre into a solution to be examined, independent of the solution applied to the surface of the other part of the fibre, although at the boundary (i. e., within the middle compartment) there might occur the mixed effect, if any, of the two solutions.

If the muscle fibre is made in contact with Ringer's solution in one of the end compartments (A) and with M/8 KCl solution in the other (B), an electric current due to the "salt potential" can be induced to flow from (A) to (B) in the medium (cf. Höber 1905), so that the part of the fibre in (A) may be brought under the cathelecrotonic influence of the current. The Ringer's solution in (A) was replaced by M/8 KCl from time to time to examine the excitablity in that part of the fibre to K-ions, and it was found that the part of the fibre in (A) became entirely insensitive to K-ions within 2~4 min. (at 18°C). Hence it may be stated that an insensibilization wave, probably of the same nature as that observed in the injured muscle, can be established by the "salt current" without the aid of mechanical injuries. If the recovery was allowed in Ringer's solution, the insensibilized part of the fibre in (A) as well as the K-poisoned part of the fibre in (B) became sensitive to K-ions once more, although the recovery was rather slow and usually not complete owing to the too much prolonged subjection of the fibre in (B) to K-ions.

In a similar sort of experiments, if M/12 $MgCl_2$ or M/12 $CaCl_2$ be given at (B), it might be expected that the part of the fibre in (A) is left unchanged, since, according to Höber (1905), the salt potential of frog muscle established between Ringer's solution and isosmotic $CaCl_2$ (or $MgCl_2$) is practically nil (less than 1 m. v., even if it exists). However, the contraction height of the fibre at (A), tested by occasional stimulations with K-ions, was diminished to 60~70 per cent of the initial untreated value in 3 min. (15~16°C), although the diminishing rate became progressively slow, so that the contraction height remained at a level of about 40 per cent of the initial value for a considerably long time (from 15 to 60 min.). Similarly the contractibility at (B) was examined, with a result that it was reduced slowly for 15~20 min. and then remained practically constant for a fairly long time. The effects in (A) as well as in (B) were perfectly reversible. It may be supposed that in the present material the surface of the fibre in contact with Ringer's solution is very slighty electro-positive (in the external circuit) with respect to the surface in contact with one of these solutions.

With a view to sending the salt current in the opposite direction in a similar sort of experiments, M/8 $NaNO_3$ and M/8 NaSCN were used in the compartment (B) (cf. Höber 1905). Thus the part of the fibre in (B) was now considered electro-positive (in the external circuit) with respect to that in contact with Ringer's solution in (A). In fact, it was shown that in the part of the fibre in (A) there took place no decay in the sensitivity to K-ions for at least 10 min. (15~16°C), although the decay did appear very gradually in the long run, owing probably to the final reversal of the salt potential reported in the case of these salts by Höber (1905). On the other hand, as would be expected from the cathodic effect of the salt potential, the part of the fibre in (B) became insensitive to K-ions in about 15 min. with NaSCN and in about 30 min. with $NaNO_3$.

From above, it may be seen that, without any sign of mechanical injury, the local insensibilization of the muscle cell is possible by an electro-chemical disturbance in the normal equi-potential relationship existing on the cell surface.

Coagulum formation

Heilbrunn (1940) has pointed out that, when a muscle fibre with both ends cut is immersed in an isotonic $CaCl_2$, a coagulum-like mass of protoplasm is formed at the cut ends, which increases with time at the expense of the normal part of muscle protoplasm, so that the total length of the fibre is markedly shortened as a consequence of the coagulum formation.

We could confirm these results by giving an injury, at a required point, to the non-injured fibre placed in M/12 $CaCl_2$. In this case it is considered that the muscle protoplasm is made to interact with the external solution at the naked surface to be changed into the coagulum. The boundary between the coagulum and the intact part does not check the free diffusion of the solutes like Ca-ions which are believed not to pass through the uninjured membrane (cf. Heilbrunn 1940 p. 89), so that the protoplasm in the adjacent region can not be left undisturbed and a new coagulum is formed there in a similar way. The cell membrane in the adjacent region is also made to be disorganized when the internal protoplasm in contact with it is disturbed in this manner. Thus the coagulum can increase, by the expense of the intact part of the fibre, to cover the entire length of the fibre.

In order to see the seat of shortening of the fibre, an analysis of the changes in distance between granules adhering on the surface of the intact part of the fibre as well as on the coagulum was made with the aid of cinematographic records taken at the time of the coagulum formation. It was found that the distance between granules is suddenly diminished when the region of the fibre between the granules is transformed into the coagulum, but the distance between granules both on the intact region of the fibre as well as both on the coagulum already formed remain constant, so long as the fibre is placed with the ends mechanically free in M/12 $CaCl_2$. It is therefore certain that in M/12 $CaCl_2$ the shortening of muscle protoplasm occurs only at the boundary between the coagulum and the intact region, and not at any other part of the fibre. However, with an isometric arrangement (i. e. with the tendon at the both ends of the fibre clamped firmely in M/12 $CaCl_2$ solution), the distance between granules on the intact part of the fibre is seen to increase slowly, owing to the tension developed at the point of the coagulum formation. That this increase in distance is purely of passive nature, can be shown by the fact that, if the distance of the granules on the intact region of the fibre is plotted against the tension artificially applied, in an isotonic arrangement, to the fibre during the progress of the coagulum formation, the curve is quite identical with that of the corresponding tension-distance relation obtained by subjecting the fibre to passive stretchings in the same medium but just prior to the injury being given to the fibre.

The distance between granules on the coagulum can not appreciately be altered by applying a similar pull at one end of the fibre, showing that the coagulum substance is by far less extensible in comparison with the intact part of the muscle fibre.

It may be said from these, that the transformation of the muscle substance into the coagulum is accompanied by a reduction in the elastic resting length of the protoplasm in the longitudinal direction of the fibre and also by an increase in the modulus of elasticity of the protoplasm. Thus the coagulum formation may be taken as a sort of "contraction" of the muscle protoplasm in the sense that the muscle protoplasm is changed into a mass of smaller elastic resting length and of greater elastic modulus.

The fact that the tension-length relation in the intact part of the fibre is not influenced by the coagulum formation established at some other part of the fibre, makes it possible to measure, in an absolute unit, the tension developed by the formation of the coagulum, if, in a fibre clamped at the two ends, the increment in the distance of granules on the intact part of the fibre is recorded on the cinematographic films and calibrated separately by applying to the same fibre various tensions of known values. By this method, it could be seen that in an isometric arrangement the tension developed is linearly proportional to the advance of the coagulum formation.

The muscle protoplasm thus changed into a round mass of coagulum seems to possess still some longitudinal arrangement in its molecular pattern, since it can be lengthenend rapidly in the original longitudinal direction, if immersed in some suitable solutions, say, N/10 HCl, although even by this means the original excitability can no more be given to the once formed coagulum.

The advancing coagulum was preceded by a region in which a slight increase in diameter of the fibre occurred, as Heilbrunn (1940) has shown, but this seemed not to be demonstrable in solutions of mono-valent cations. On the other hand, it was very often observed that the advancing coagulum was preceded also by a region, in which droplets immiscible with the external aqueous solution were "excreted" on the cell surface, and this took place not only in $CaCl_2$ solution but also in many other solutions.

In order to see the effect of various solutions, Ringer's solution streaming over the non-injured fibre placed in the narrow muscle chamber was replaced by a solution to be examined, and an injury of a size enough to cover the full cross-section of the fibre was given at one end of the fibre after the stimulation effect, if any, of the replaced solution had subsided by adaptation. The stimulation effect was observed in some of the solutions (K-salts, Na-salts, sugars etc.) but not in others ($CaCl_2$, $MaCl_2$ etc.). However, even in the non-stimulant solutions, the injury was given to the fibre only after a considerable time of adaptation. However, in order to compare the effect of various solutions in one and the same fibre, the solution flowing through the muscle chamber had to be changed suddenly from one to the other during the progress of the coagulum formation. In this case the sequence of the application of the solutions was selected in an appropriate way so as not to evoke the stimulation by the replacement of the solution. If this precausion was taken properly, since the process of the coagulum formation was rather slow as compared with the completion of the replacement of solution and moreover the measurement was done always after a considerable length of time of adaptation, the results given below seemed practically independent of the nature of the solution employed previously. Lines representing the "length of coagulum" vs. time relation (like Fig. 2 A) were constructed from cinematographic records of the coagulum formation obtained under a suitable magnification, and from the inclination of these lines, the rate of advance of the front of the coagulum along the fibre was determined, as an average, with respect to various solutions. The rate was satisfactorily constant for a considerable duration and practically independent of the solution previously applied to the fibre, as is seen from Fig. 2 A, although the rate was usually somewhat enhanced when the front of coagulum came near the end of the fibre or when the front of coagulum came nearer to another front of coagulum advancing in the opposite direction. The rate seemed to be much influenced by temperature, but, even at the identical temperature, it was quite different for different preparations, as will be seen from the following data obtained with M/12 $CaCl_2$ (pH=8.0).

No. of Fibre	1	2	3	4	5	6	7	8	9
Temp. (°C)	30.0	29.0	27.5	30.5	27.0	30.5	30.5	31.0	30.0
Rate(microns/sec)	29	20	39	30	36	4.3	5.8	3.2	28
No. of Fibre	10	11	12	13	14	15	16	17	18
Temp. (°C)	30.0	30.0	30.0	31.0	31.0	30.5	30.5	15.0	16.0
Rate(microns/sec)	10	14	8.7	12	8.8	20	19	10	7.3
No. of Fibre	19	20	21	22	23	24	25	26	27
Temp. (°C)	16.5	13.0	13.0	17.0	13.5	12.5	13.5	17.0	15.0
Rate(microns/sec)	13	27	4.2	16	8.1	19	17	13	14

It follows from this, that comparison should only be made between the data obtained in one and the same fibre.

Heilbrunn (1940 p. 91 and 92) has reported that Sr and Ba behave like Ca while Mg is effective only in relatively high concentration, and that no such shortening appears in the isosmotic solutions of KCl, NaCl or in Ringer's solution. In our experiments, however, the shortening (coagulum formation) was observable in all of these solutions, although the rate of formation was much dependent on the nature of solution.

Example 1

Solution		M/12 $CaCl_2$ pH=8.0	M/12 $SrCl_2$ pH=6.8	M/12 $BaCl_2$ pH=6.8	Ringer pH=7.2	Temp. (°C)
Rate (microns/sec)	Fibre A_1	17	9.4	3.6	0.54	13.5
	Fibre A_2	19	10.0	1.2	0.31	12.5
	Fibre A_3	27	8.2	2.1	0.23	13.0

Example 2

Solution		M/12 $CaCl_2$ pH=8.0	M/12 $SrCl_2$ pH=6.8	M/12 $BaCl_2$ pH=6.8	M/12 $MaCl_2$ pH=7.2	M/8 KCl pH=7.1	Temp. (°C)
Rate (microns/sec)	Fibre B_1	14	10	3.4	1.6	0.32	15.0
	Fibre B_2	13	5.4	3.7	1.7	0.26	17.0

Example 3

Solution		M/12 $CaCl_2$ pH=8.0	M/12 $MgCl_2$ pH=7.2	M/24 $MgCl_2$ pH=7.1	Ringer pH=7.2	Temp. (°C)
Rate (microns/sec)	Fibre C_1	14	2.5	0.20	0.51	30.0
	Fibre C_2	8.7	1.8	0.20	1.5	30.0

Example 4

Solution		M/12 $CaCl_2$ pH=8.0	M/8 KCl pH=7.1 by $KHCO_3$	M/8 NaCl pH=7.0 by $NaHCO_3$	M/16 Na-citrate pH=7.7	M/8 Na phosphate pH=7.0	Temp. (C°)
Rate (microns/sec)	Fibre D_1	39	0.83	0.19	1.3	0.04	27.5
	Fibre D_2	36	0.74	0.21	1.8	0.04	27.0

The fact that the coagulum formation appears in the fibre placed in M/8 KCl, indicates that the shortening mechanism remains unabolished in the non-irritable state of muscle poisoned with K-ions. In the following lines, data are given to show the effect of dilution of M/12 $CaCl_2$ with Ca-free Ringer's solution (the results with fibre E_1 being represented in Fig. 2).

Example 5

Solution	Volume ratio of mixture (M/12 $CaCl_2$: Ca-free Ringer)	1 : 0	3 : 1	1 : 1	1 : 3	0 : 1	Ringer	Temp. (°C)
Rate (microns/sec)	Fibre E_1	1.2	3.9	2.3	1.5	0.2	0.15	13.0
	Fibre E_2	10.0	10.0	5.8	3.9	0.18	1.2	15.0

(pH=8.0 in M/12 $CaCl_2$, 7.2 in Ca-free Ringer and 7.2 in Ringer)

The formation of the coagulum seems to be much retarded by an increase in the osmotic pressure of the medium, as will be seen in the following example, in which the measurement is done in M/12 $CaCl_2$ made up with M/4 NaCl.

Example 6

Solution		M/12 $CaCl_2$ pH=8.0	M/12 $CaCl_2$•M/4 NaCl pH=8.0	Ringer pH=7.2	
Rate (microns/sec)	Fibre F_1	28	7.2		30.0
	Fibre F_2	10	4.2		30.0
	Fibre F_3	19	4.9	1.2	30.5

It may be clear from the following examples, that pH is one of the most important factors to determine the rate of the coagulum formation. This is true with K-ions as well as with Ca-ions. The rate falls off as pH is reduced, and attains a minimum at a slightly acidic pH, below which the rate increases markedly with further decrease in pH.

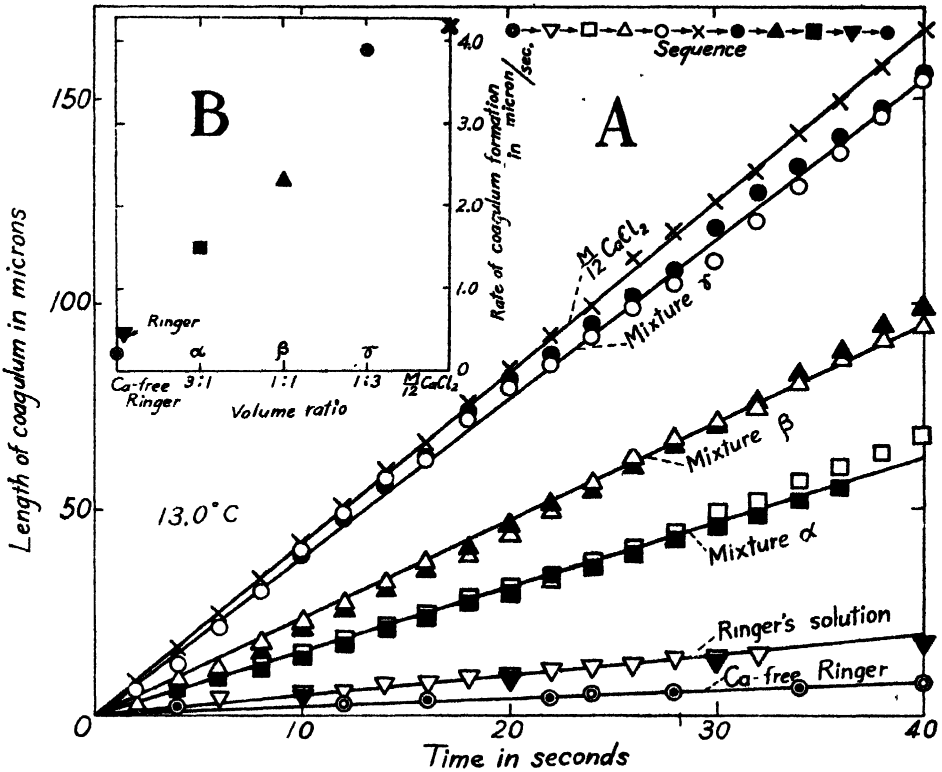

Fig. 2. Rate of coagulum formation as influenced by Ca-ion concentration

The non-injured single muscle fibre (biceps) was connected with a very light isotonic arrangement constructed in the muscle chamber through which Ringer's solution was made to flow. The flow of Ringer's solution was substituted by a flow of Ca-free Ringer, and, when the contractions evoked by this reduction of external Ca-ions had subsided, an injury was given at one end of the fibre. Thus the coagulum was made to form at the injured spot and increased gradually at the expense of the adjacent intact part of the fibre. The length of muscle protoplasm which was transformed into the coagulum, and which is denoted here as "length of coagulum" for convenience, could be known from the position of the front of the coagulum spreading from the injury, if carbon black granules had previously been adhered on the surface of the fibre as a measure of the resting length of the parts of the fibre. The advance of the coagulum was recorded cinematographically under the microscope, and, from the records, the "length of coagulum" vs. time relation could be determined as is shown in Fig. 2 A. This procedure was repeated with changing the external medium from weak Ca- to strong Ca-solutions and then from strong Ca- to weak Ca-solutions, the sequence being shown at the top of Fig. 2 A by arrows connecting a chain of marks, in which each mark represents the measurement whose data are given with the same marks in Fig. 2 A proper.

In Fig. 2 A are plotted 11 sets of such data with "length of coagulum" on ordinate against time on abscissa, and straight lines are drawn to fit all the data obtained in one and the same external medium. These data show that the rate is practically constant for a fairly long time. The composition of mixture α, β and γ are known from Fig. 2 B.

From the inclination of these lines, the mean rate of coagulum formation was determined and is plotted in Fig. 2 B against the volume ratio in the mixture of M/12 $CaCl_2$ and Ca-free Ringer. It will be seen that the rate is much accelerated in the medium rich in Ca-ions.

Example 7 Solution: M/12 $CaCl_2$ (pH by N/10 HCl)

	pH	8.0	6.6	4.8	3.2	2.1	Temp °C)
Rate (microns/sec)	Fibre G_1	4.3	2.4	5.2	52.0	—	30.5
	Fibre G_2	5.8	3.7	5.0	39.0	78.0	30.5
	Fibre G_3	3.2	2.6	3.6	40.0		31.0

Example 8 Solution: M/8 KCl (pH by M/8 $KHCO_3$)

	pH	6.7	7.1	7.5	8.2	9.0	Ringer	Temp (C
Rate (microns/sec)	Fibre H_1	0.17	0.21	0.29	0.43	1.1	-	27.5
	Fibre H_2	0.21	0.30	0.33	0.37	0.75	1.8	27.5

It may be remarked here that it happened in many cases, that the rate is slighly but unmistakably high in a medium of K-ions as compared with that in Na-solutions with the same anions. One of the examples is seen in Example 1 above given. However, in view of the result given in Example 8, this seems to be explained on the basis that the muscle protoplasm tends to be more alkaline in the medium of K-solutions (Tipton 1936).

Heilbrunn (1940) has pointed out that the coagulum is formed in solutions of Na- or K-oxalate. The following data, together with those in Example 1, indicate that the coagulum is formed in solutions containing citrate at a rate higher than in Cl-solutions

Example 9

Solution		M/12 $CaCl_2$ pH 8.0	M/8 K-phosphate pH 7.0	M/16 K citrate pH 7.8	M/8 KCl pH 7.1	Temp. °C)
Rate (microns/sec	Fibre I_1	29	0.4	3.1	-	30.0
	Fibre I_2	20	0.2	3.2		29.0
	Fibre I_3	30		3.8	1.3	30.5

It is true that Ca-ions (and other divalent cations) are conspiciously effective for this reaction, but the fact that the coagulum does form in a medium of citrate (or in oxalate) at a rate decidedly higher than in Cl (cf. Example 1 and 9), may suggest that the reaction is specific neither to the over-concentration of Ca-ions nor to the combination of Ca-ions with some intracellular structure.

On the other hand, as is seen from the following data (see also Example 1 and 9), the coagulum formation becomes very slow, or practically stops, in the medium rich in phosphate anions.

Example 10

Solution	M/12 $CaCl_2$ pH=8.0	M/8 NaCl pH=7.0	M/8 Na-phosphate pH 7.0	M/16 Na phosphate pH=7.1	M/8 K-phosphate pH 7.0	Temp. (°C)
Rate (microns/sec)						
Fibre J_1	16	0.13	0.04	0.05	0.06	17.0
Fibre J_2	8.1	0.12	0.03	0.04	0.07	13.5

Example 11

Solution		Volume ratio of mixture (M/8 NaCl: M/16 Na-phosphate) 1 : 0	3 : 1	1 : 1	1 : 3	0 : 1	M/12 $CaCl_2$	Temp. (°C)
Rate (microns/sec)	Fibre K_1	0.26	0.08	0.05	0.05	0.05	7.3	16.0
	Fibre K_2	0.14	0.08	0.08	0.06	0.03	13	16.5

(pH=7.1 in M/16 Na-phosphate, 7.0 in M/8 NaCl and 8.0 in M/12 $CaCl_2$)

It may be considered that, in the normal state, the internal protoplasm is prevented by the cell membrane from being mixed with the external medium, but when it is made to come in contact with the external solution at the naked surface, an ionic disturbance is expected to occur at this point. At the naked surface, the muscle phosphates which are believed to constitute the main anions within the fibre (cf. Fenn 1936), must be removed quickly (by precipitation) in the case of such ions like Ca, Sr or Ba, or very slowly (through diffusion) in the case of solutions with anions other than phosphate (e. g. Cl or citrate). In fact, the balance of evidences so far obtained seems rather to be in favour of the view that reduction in concentration of the intracellular free phosphate anions constitutes the initiation for the chain of events involved in the reaction of coagulum formation. The fact that the coagulum formation is practically stopped in a phosphate-rich medium irrespective of its cation nature, may be ascribable to the situation that, despite of noticeable disturbance in cations, there takes place no reduction in the concentration of free phosphate in muscle when the protoplasm is mixed with such a solution. As is seen from the following results, the coagulum formation occurs even in such a medium in which the active participation of the external ions is rather difficult to consider, i. e., in non-electrolyte solutions, in which, however, the muscle phosphates can be diluted by mixing.

Example 12

Solution		M/12 $CaCl_2$ pH=8.0	M/4 Glucose pH=6.3	M/4 Sucrose pH=6.6	Ringer pH=7.2	Temp. (°C)
Rate (microns/sec)	Fibre L_1	12	1.6	1.6	0.81	31.0
	Fibre L_2	8.8	1.4	1.5	1.6	31.0
	Fibre L_3	20	1.7	1.7	1.2	30.5

It may be very interesting, if the disturbance in the intracellular phosphates is linked to the chain of chemical reactions (i. e. phosphagen breakdown etc) considered to occur during the restitution phase of muscle contraction.

According to Francis (1937), in the K-phosphate solution (0.116 M, pH=7.0), the skeletal muscle of frog gives no potential difference between the intact surface and the injured end. Therefore, it might be conceivable that the inhibition of the coagulum formation in M/8 K-phosphate above reported is related to an absence of injury current. However, this explanation seems rather improbable, since the coagulum is inhibited to form also in M/8 Na-phosphate, in which the injury current would probably be established as Na-ions differ in mobility from K-ions.

It is also interesting to note that even in the K-poisoned fibre or in the fibre over which the insensibilization wave has swept, the coagulum forms similarly at the naked surface of the protoplasm which is brought in contact with Ca-ions. However, if the muscle is made non-irritable by being immersed in hot water (e. g. 60°C), acidic solutions (e. g. N/10 HCl) or hypotonic solutions (e. g. distilled water), the fibre can no more form the coagulum even in M/12 $CaCl_2$ solution. The fibre poisoned (by micro-injection) with M/16 $AlCl_3$ fails also to form the coagulum by Ca-ions.

In passing, it may be added that, so far as we had the chance to make the tests, the coagulum formation due to Ca-ions could be observed only in striated muscles [Amphibians, Teleosts, Elasmobranchs, Insects (leg muscles only), Crustaceans and Molluscs], but, as Meigs (1912) and Speidl (1936) have described briefly, this could not be demonstrated in smooth muscles [Amphibians (frog's stomach muscle), Tunicates, Coelenterates, Annelids, Sipunculoids, Molluscs and Echinoderms]. On the other hand, the K-contracture was found in all of these muscles (smooth as well as striated). The wing muscles of many insects, though the cross striations were clearly seen in them, did not show the coagulum formation, when the cut end was treated with M/12 $CaCl_2$.

Micro-injection experiments

The action of various solutions on the muscle protoplasm may be studied most conveniently by making use of the coagulum formation above described. However, it is more desirable to bring the solution directly to the protoplasm, leaving all the other part of the fibre in the normal state as far as possible. For this reason, injection of solutions into the fibre was done with micropipettes having the perforated tip of 2~5 microns in external diameter. The technique of the micro-injection was fundamentally the same as that used in the case of *Paramecium* (Kamada 1938) and of sea-urchin eggs (Kamada 1941).

The solutions tested so far may be divided into three classes, according to the effect on the muscle protoplasm.

I M/12 $CaCl_2$, M/12 $SrCl_2$, M/12 $BaCl_2$.

II M/12 $MgCl_2$, M/12 Oxalic acid, M/4 Glucose, Distilled water, M/8 NaCl (pH=7.0 by $NaHCO_3$), M/8 KCl (pH=7.0 by $KHCO_3$), M/8 KCl (pH=9.0 by $KHCO_3$), M/8 $KHCO_3$, M/16 Na-citrate, M/16 K-citrate

III M/8 and M/16 Na-phosphate (pH=7.0), M/8 and M/16 K-phosphate (pH=7.0)

These solutions were injected into the isolated muscle fibre placed quietly in Ringer's solution. In most of these injection experiments, single fibres isolated from sartorius muscles with both ends cut were used, for convenience, although, with such fibres, the injection had to be made immediately after the preparation, otherwise the insensibilization wave from the cut ends might have reached the region to be tested. The time required for insensibilization was, however, known from separate measurements, and the injection could be made, so-to-speak, under the normal condition of the fibre.

The injection causes arround the tip of the micro-pipette a localized slow contraction (a hump-like swelling due to local shortening and thickening of the fibre, associated with a localized movement of protoplasm toward the tip of the micro-pipette). This is very obvious and more or less quick with solutions I. With solutions II, however, the reaction occurs very slowly and requires a larger amount of solution to be injected, although the contraction evoked appears fundamentally (except for the velocity) similar to that induced by solutions I. Since, in a control experiment, an injection of paraffin oil (Merck) is effectless, the simple mechanical effect of injection can not be the cause of this reaction. The contraction brought about by M/16 K-citrate, though weak and slow as in the general case with solutions II, can be conducted to the adjacent region; the detailed feature of this reaction will be given separately below. With solutions III, no local contraction can be elicited.

Na-phosphate, when injected, ought to give rise to a considerable cationic disturbance within the muscle, nevertheless no contraction occurs as a consequence. This seems theoretically rather important, since it may be suggested from this, that the contraction of the muscle protoplasm has some relation to the internal anionic disturbances rather than the internal cationic disturbances. This constitutes an interesting contrast with the well known fact that the muscle is generally very sensitive to the cationic disturbances in the external medium and far less to the external anionic disturbances.

It seems possible to account for these results in the same line with the coagulum formation. Solutions I may diminish the internal free phosphates rapidly by precipitation, so that the local contraction ensues with a more-or-less high speed. In the case of solutions II, the reduction in concentration of the muscle phosphate may probably be brought about by dilution of the protoplasm with the injected fluid, and, as a matter of fact, the reaction requires a larger amount of injection in comparison with solutions I. The contraction due to injection of distilled water may be explained most reasonablly in this line. The result that injection of solution III is effectless, may readily find its explanation in that an addition of these solutions gives rise to no dilution of the muscle phosphate. In the case of solutions I in general, the contracted protoplasm looks darker than in the case of solution II, owing probably to the dense granules of the precipitated phosphate compounds.

If, on the other hand, the contraction induced by injection of, say, M/8 NaCl is due to a specific action of the newly introduced Na-ions (or Cl-ions), an injection of some smaller amount of concentrated NaCl solution may be expected to be equally effective. However, an injection of 1 M NaCl is by no means more effective for contraction than that of M/8 NaCl or even of distilled water.

The protoplasm at the injected region usually forms, in association with the contraction, an internal coagulum which increases after the retraction of the micro-pipette, owing probably to an inward penetration of the external solution (Ringer) through the pore formed by the insertion of the micro-pipette. However, when the micro-injection is made quite successfully (viz., with practically invisible mechanical injury), and the injected amount of solution does not exceed a certain limit, the local contraction elicited disappears spontaneously, i.e., the cross-striations, which have been condensed at about the injected spot, are soon made to scatter again, and the fibre can restore the original state once more so as to respond to a second injection as before. Hence the reaction induced by the micro-injection may be considered as fundamentally of a reversible nature, and the recovery is possible only if the disturbances induced does not exceed the repairing power of the protoplasm. The rate, and also the grade, of the recovery seem to depend on the degree of the protoplasmic disturbances; the more advanced is the disturbance, the longer time is required for the recovery and in a further advanced degree of disturbance the recovery may become incomplete. In view of these relations, although the coagulum formed in the injured fibre placed, say, in M/12 $CaCl_2$ is by no means reversible, the irreversibility may be taken as due to the profound modification of protoplasm induced with an infinite supply of the disturbing Ca-ions from without. On this basis the coagulum formation in general may be supposed to be also of a reversible process at least at the earlier stages of the reaction.

M/16 K-citrate differs from other solutions belonging to II in that, in the recovery phase of contraction induced by the injection of this solution, the swelling shifts to the adjacent regions in both directions. Thus two waves of swelling often start from the injected region to travel along the fibre at a very slow rate. The swelling is preceded by an apparent movement of protoplasm from the resting region toward the region just about to swell. The conduction is decremental; the swelling becomes smaller as the wave advances, and finally the wave fades away. The extent, to which the wave can be conducted, is not definite, depending on the size of the swelling at the start: the larger the swelling, the longer the distance of the conduction. The final disappearance of the conducted wave is not always simultaneous in one cross section of the fibre, i.e., an advancing swelling disappears often only on one side of the fibre, whereas the swelling of the other lateral half survives to progress. When the swelling has been conducted away from the injected spot, a second swelling appears there to be conducted as before. The second swelling tends to become smaller than the first. The effect of injection of M/16 K-citrate subsides usually after the injected spot sends out a few number of swellings in slow succession. The wave of swelling, while advancing in one direction often sends out a wave in the back direction, and this seems to indicate that, after the passage of the swelling wave, no absolute refractory state is left in the track of conduction. There is an unmistakable tendency that the propagation of swelling above described is easier to occur with fibres of smaller diameter and in fresh preparations.

It must be noticed that in all the micro-injection experiments the contraction (and the conduction) was evoked only in the fibre injected with the solution but never in the fibre which was laid, for the sake of comparison, in the same medium close to the fibre under investigation, so that the possibility was excluded that the solution in question might act on the fibre from without by being deposited, as an error of micro-injection, in the external medium.

SUMMARY

In frog's skeletal muscles, if the cell membrane is removed locally, two kinds of protoplasmic disturbances, different in speed of propagation, are initiated from the naked surface of the protoplasm to spread over the entire length of the fibre.

If the muscle protoplasm is made to interact with the external solution at the naked surface, the protoplasm is changed into a mass which may be called "coagulum" from its appearance. The coagulum is of a smaller elastic resting length and of a larger elastic modulus as compared with the intact muscle protoplasm. The boundary between the coagulum and the intact protoplasm does not check the free passage of the solutes, so that the protoplasm in the adjacent region can not be left undisturbed and a new coagulum is formed there in a similar way. The cell membrane in the adjacent region is made to be disorganized, if the internal protoplasm in contact with it is disturbed in this manner. Thus the coagulum can increase, by the expense of the intact part of the fibre, to cover the entire length of the fibre. Results obtained have led to a suggestion that the coagulum formation may be initiated by a diminution of the internal free phosphate. In fact, the coagulum formation is more or less independent of the disturbance in the cationic make-up of the protoplasm. The direct action of ions on the naked protoplasm is examined more closely with micro-injection methods. It seems that the process of the coagulum formation is of a reversible nature at least in the earlier parts of the chain of reactions, although, after the completion of the reactions, it is impossible to regain the original state.

At a rate higher than that of the spreading of the coagulum, another "wave" is started from the naked surface, by which the intact part of the fibre is made non-irritable. This is termed the "insensibilization wave" for convenience. The protoplasmic modification induced by this wave is by no means detectable upon inspection with a microscope, and the injured fibre, over which the wave has swept, appears quite the same as the normal irritable fibre, except for the region at which the coagulum has been formed. The insensibilization seems to be brought about by the injury current established between the naked surface and the intact part of the fibre. In fact, the insensibilization wave can be retarded by antagonizing the injury current with an electric current led from an external source. The fibre once insensibilized can be made irritable again by sending an electric current in the direction opposite to the injury current or by immersing the fibre in an isosmotic Ca-solution. Thus it is considered that the insensibilization process is reversible at least partly. Even in the non-injured muscle, a continuous electric current, derived from the salt potentials of the fibre as well as from an external source, can induce the insensibilization in the cathodic region. The insensibilization wave

does not abolish the contractile mechanism of muscle protoplasm, so that the coagulum can be formed in the region in which the insensibilization has been established.

The local insensibilization of muscle fibre can be studied by the photographic registration, taken at the time of stimulation, of the movement of granules adhering on the surface of the fibre. For this technique, stimulations with K-ions may be used most conveniently. On this account, the response of non-injured single fibres to K-stimulation is described in some detail for the sake of comparison with that of the injured fibres.

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APPENDIX

EXPLANATION OF PLATES LIII AND LIV

The non-injured single muscle fibre (biceps), placed in Ringer's solution in the muscle chamber, was clamped firmly at one tendon and connected by the other tendon with a micro-isometric lever of a period of 26 milliseconds. The beam of light reflected from a minute mirror attached to the isometric lever was focused on a photographic plate settled in a sliding camera. The light spot on the photographic plate was made to deviate from the resting position to a distance approximately proportional to the tension developed in the fibre, so that the usual type of registration of the muscle contraction was obtained on the sliding photographic plate. The result is shown by the curve T in Fig. 3, or by the white tracings in the Plate-figures, in which the horizontal axis represents the time and the vertical axis the tension. The vertical lines in the Plate-figures indicate the time interval of 0.02 sec. in I and of 0.5 sec. in II, III and IV. The tension was calibrated separately with known loads applied to the system of isometric lever, and the scale of tension thus determined is given on the left-hand side in Plate-figures.

On the surface of the fibre, carbon black granules were adhered so as to give a train of dark spots on the contour line of the fibre in the lateral view. These dark spots were focused, through a very narrow slit and under a suitable magnification, on the same photographic plate.

If no local movement occurred in the fibre, the loci of the dark spots on the sliding photographic plate were a set of straight lines in parallel with the base line of the tension, but if some local movement was induced in the fibre, the parallel relationships were disturbed (cf. the horizontal parallel lines and their distortion in Plate figures). In this way both the local movement of the muscle fibre and the total tension developed in the fibre could be recorded simultaneously. The dark areas at the top and at the bottom of Plate figures represent the loci of the tendons attached to the ends of the fibre. The scale on the right hand side of Plate figures enables us to measure the distances between the granules in an absolute unit.

The Plate-figures are four examples selected from a series of records obtained in one and the same fibre at 13.5°C, so that the registered lines ought to be followed from one record to the other, if the records are arranged, according to the time sequence of the registration, in an order shown in Fig. 3, in which I, II, III and IV correspond to the Plate figures I, II, III and IV respectively.

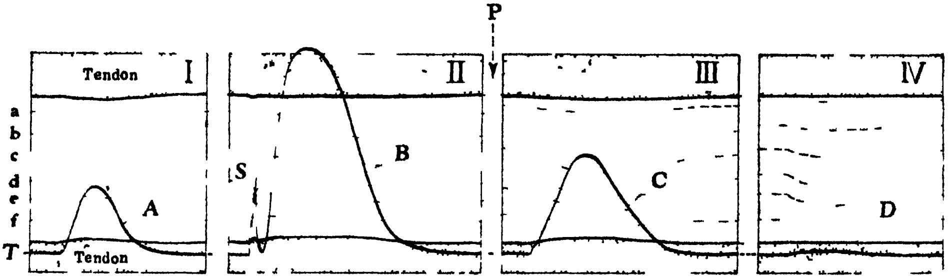


Fig. 3.

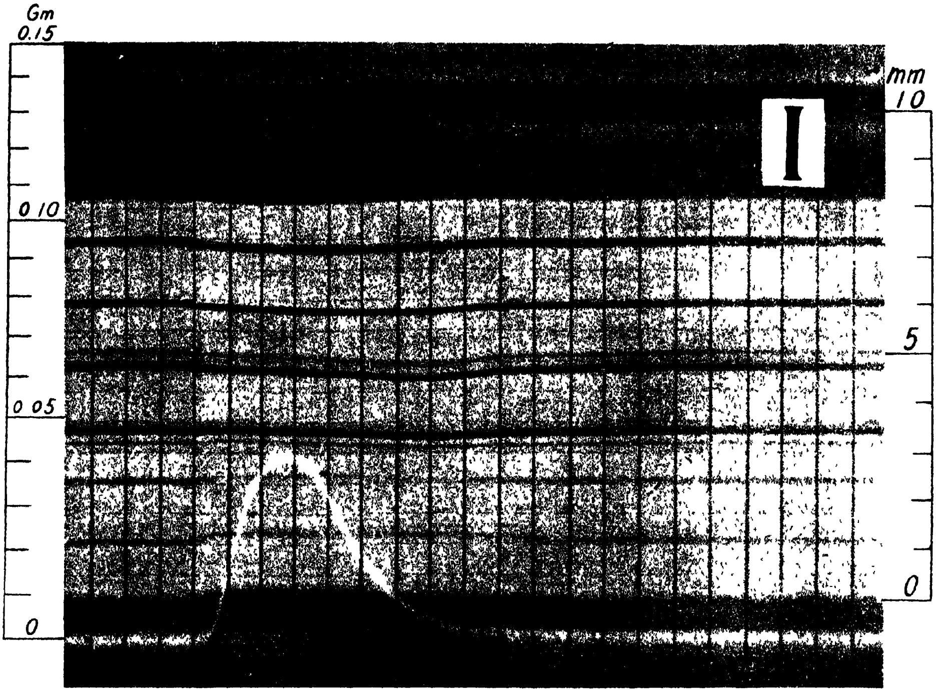
In Fig. 3, A represents the isometric contraction of the fibre evoked by a single supermaximal break induction shock applied with a pair of long Ag-AgCl electrodes placed in parallel with the longitudinal axis of the fibre. At the beginning of contraction, the loci of the granules tends to converge towards the region between c and d, although in the later part of contraction they seem to converge toward the region between d and e (cf. also Plate figure I), indicating that, in spite of the fibre being stimulated evenly with the transverse current, the response is not synchronous over the entire length of the fibre. We are inclined to take this irregularity in response as due to the difference in reaction time of the elementary parts of the fibre rather than the non-uniformity of the elastic properties over the entire length of the fibre in the excited state, since, for example, a more or less identical result could be obtained by a local electrical stimulation of the fibre with the combination of a small cathode and a large anode. Be that as it may, it is important to remark that, in spite of the total length of the fibre being kept isometric, some fraction of the fibre can shorten locally by compensation of the other fraction of the fibre.

Subsequently to a series of such an electrical stimulation, when the fibre had restored the original excitability, the Ringer's solution flowing through the muscle chamber was substituted by M/8 KCl (pH=7.1 by $KHCO_3$) streaming in the direction from a to f in Fig. 3 for a short time (10~15 sec.), and then the fibre was allowed to recover in running Ringer's solution. The resulting response is given in II. In this case, the initial twitchings (S) appeared separately from the long sustained contraction (B). The loci of granules indicate that, in the initial twitchings S, a set of contractions seem to commence at various spots on the fibre with various reaction times, while in contraction B, the response commences at the upper end at which the K-solution comes first in contact with the fibre. If A is compared with B, it will be clear that the muscular contraction is by far stronger with K-stimulation than with electrical stimulation.

It was usually found that, so long as the fibre remained uninjured, and if the recovery was complete after the K-poisoning, a series of practically identical responses could be obtained for hours with the repetition of K-stimulations, although the initial twitchings disappeared after a short series of responses.

However, in the present case, an injury of about 0.6 mm in length was given, with points of forceps, at the upper (in Plate-figures) end of the fibre about 2 minutes after the contraction B was over (P in Fig. 3 indicates the moment at which the injury was given). The subsequent stimulations with the same KCl solution produced contractions which became progressively smaller with time (the contraction C: about 5 min. after P, and D: about 10 min. after P), and the same stimulation given about 15 min. after P induced no visible response in the fibre. During the time from II to III as well as from III to IV in Fig. 3, the distance between the upper tendon and the granule(a)was diminished owing to the coagulum formed at the upper end, but the tension developed by the coagulnm formation was rather small so that the base line of tension (T) was practically not modified during this time.

The loci of granules show that in III the lower parts of the fibre (d, e, f) are made to shorten by the stimulation, while the upper parts of the fibre (a, b, c) which are proximal to the injury, can no more respond to K-ions and are lengthened by the contraction of the lower parts of the fibre. Thus, the insensibilization of the fibre is seen to spread from the injury. In IV, the insensibilization is further advanced as compared with that in III. It can also be noticed that the decay in contraction due to the injury is clearly associated with the insensibilization. In III and especially in IV, it may be pointed out that, in spite of the decay of tension of the fibre, the local shortening at the lower part of the fibre appears rather noticeably. This is probably due to the situation that in the insensibilized area (at the upper part of the fibre) the stimulation fails to induce the local shortening and hardening of the protoplasm so that the shortening at the lower part of the fibre can be established more or less easily by a compensatory lengthening of the still extensible upper part of the fibre.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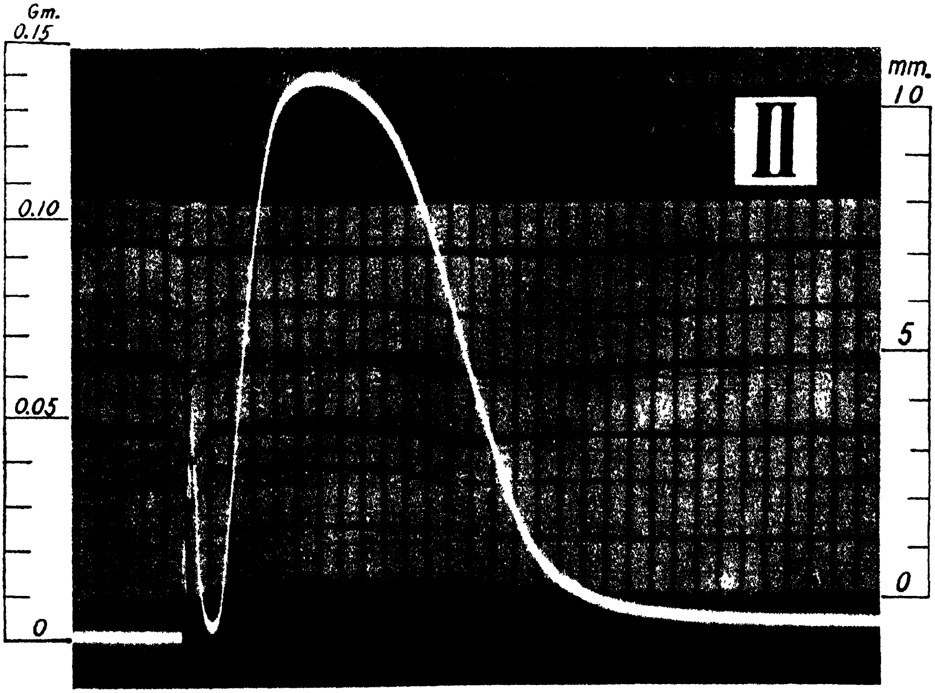
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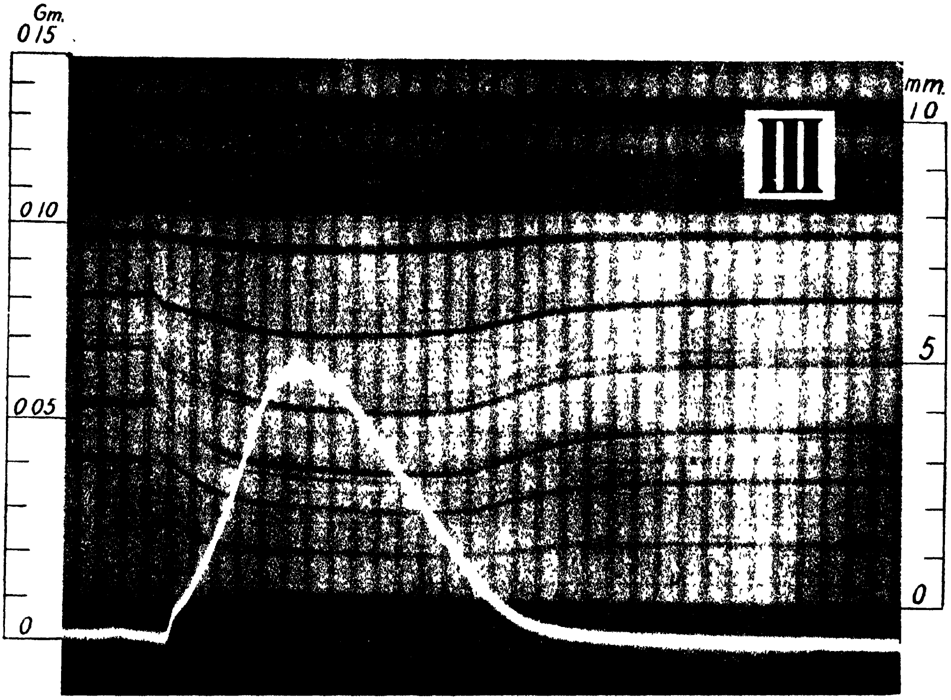
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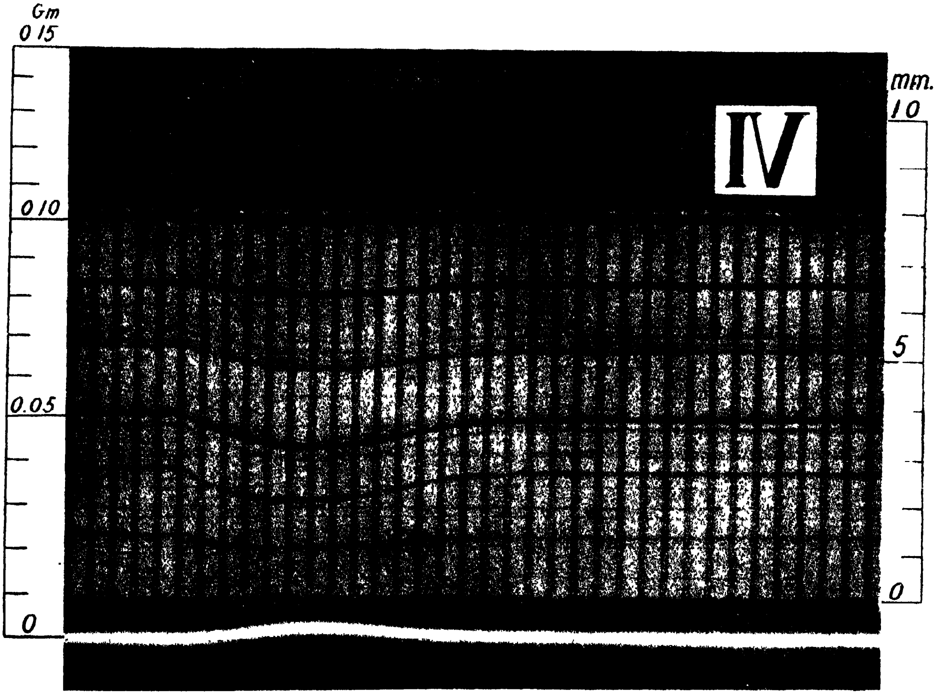
IV

Abstracts

1. On the Physiology of Reef Corals. IV. The Growth of *Goniastrea aspera* Measured from Numerical and Areal Increase of Calyces. Siro KAWAGUTI. [Palao Trop. Biol. Stat. Stud., 2 (2), (1941), 309-317, 2 Text-figs., 3 Tabs.]—Increase in the number of polyps in *Goniastrea aspera* with flattened shape was examined for the period of 65 days with the result showing that the mean rate of increase for the colonies having more than 15 polyps is 0.21, annual increase being expected to be 3.42 times of initial numbers of polyps. Numerical increase of calyces was checked by the growth in weight, the equation $\sqrt[3]{W}=0.31\times\sqrt{N}+0.17$ having been obtained from a study upon the massive type of the coral. A comparison of the surface area per polyp in 3 representative colonies was made and it was suggested that deformation of a colony might induce the increase of surface area of each calyx. M. Enami.

2. On the Physiology of Reef Corals. V. Tropisms of Coral Planulae, Considered as a Factor of Distribution of the Reefs. Siro KAWAGUTI. [Palao Trop. Biol. Stat. Stud., 2 (2), (1941), 319-328, 3 Text-figs.]—Experiments were carried out to study the mechanism of distribution of the planulae of *Acrhelia horrescens*, *Pocillopora damicornis*, *Seriatopora hystrix* and *Euphyllia glabrescens* paying special attention to their tropistic characters. As the result it was indicated that the positive photoxis and the negative geotaxis of the planulae, being assisted by other physiological as well as morphological properties, would play in co-operation significant role in the distribution of the species investigated. The intensities of light for the positive phototaxis of planulae were known to be in the order of *Pocillopora* > *Seriatopora* > *Acrhelia* > *Euphyllia*, such variation being possibly associated with variation in the amounts and arrangements of the zooxanthellae in the tissues of respective planulae. The zooxanthellae were found to be mainly distributed in the ectoderm in *Euphyllia*, while in the other species they are included in the endoderm exclusively. M. Enami.

3. The Relation between the Foraminifera and Deposits of the Java Sea. (Japanese with English résumé.) Yosine HADA. [Journ Oceanogr. Soc. Japan, 2 (4), (1943), 27-36, 2 Text-figs., 2 Tabs.] Foraminiferan fauna in the shallow area of the Java Sea surrounded by Java, Sumatra and Borneo was inspected as regards its bearing upon the nutritiveness of deposits. Distribution of Foraminifera was found to be significantly dependent upon the composition of deposits, the animals tending to increase with increase in sandy elements to attain at maximum 92% of total amount of the deposit in the south eastern area of Borneo and to decrease with increase in muddy elements to be reduced to 0.1% in 3 regions with clayey deposits. There are notable differentiations of the animals in those specific to sandy deposits such as, *Reophax scorpiurus, Textularia foliacea, T. goësii, T. conica, Operculina complanata, Peneroplis pertusus, Amphistegina lessonii, Siderolites tetraedra, Planorbulina larvata, Alveolinella boscii*, etc., and in those adapted to muddy deposits such as, *Quinqueloculina lamarckiana, Q. bicostata, Spiroloculina planulata, Eponides praeciectus, Rotalia schroeteriana, R. pulchella*, etc. *T. agglutinans, Bigenerina nodosaria, Q. reticulata, Cribrolinoides curta*, etc. were found widely distributed irrespective of the nature of deposits. Quantitative distribution of the pelagic Foraminifera was known to be closely associated with the character of the plankton in respective regions. M. Enami

4. On the Metamorphosis of *Pterothrissus gissu* Hilgendorf. (Japanese.) Kiyomatu MATUBARA. [Res. Bull. Imp. Fish. Inst., 35 (1), (1942), 1-23, 1 Pl., 10 Text-figs.]—Detailed examination of a catch of *Leptocephalus*, which to all probability belongs to the young of *Pterothrissus gissu*, made a deduction possible concerning the main events occurring with the advance of metamorphosis in this species of fish. A note on the habitat of this fish is added.

M Enami.

5. Host-Parasite Interaction in the Experimental Population of the Azuki Bean Weevil, *Callosobruchus chinensis* (L.). III. The Effect of Host Density on the Growth

of Host and Parasite Populations. (Japanese with English résumé.) Syunro UTIDA. [Ecol. Rev., 9 (1), (1943), 40-54, 5 Text-figs., 6 Tabs.] — Assuming that the population density of *Callosobruchus chinensis* may significantly influence the multiplication of the weevil itself, primarily determining the equilibrium state of its living density under a given environmental condition, the author attempted to see how far the circumstance operates under co-existence of a parasitic insect, *Neocatolaccus mamezophagus*, that attacks the weevil. It was known that interaction between the density of the host and that of the parasite took place in such a manner that the equilibrium population of the host depends rather upon its own density than upon the numbers of the parasite. Namely, the multiplication of the host weevil is likely to be controlled through the indirect influence of the parasite which affects the population density of the host.

M. Enami.

6. **Report on the Calcareous Sponges obtained by the Zoological Institute and Museum of Hamburg. Part II.** Senji TANITA. [Sci. Rep. Tôhoku Imp. Univ, IV. (Biol.), 17 (2), (1942), 105-135, 2 Pls., 9 Text-figs.] -- Description of 19 species including 6 new species of Calcarea collected in the neighborhood of the Strait of Magellan by the Zoological Institute and Museum of Hamburg. New species reported are *Leucosolenia feuerlandica*, n. sp., *Vosmaeropsis inflata*, n. sp., *V. ovata*, n. sp., *Leucandra astricta*, n. sp., *L. reniformis*, n. sp., and *L uschuariensis*, n. sp.

M. Enami.

7. **Studies on Freshwater Bryozoa of Japan. III. Freshwater Bryozoa of Hokkaido.** Makoto TORIUMI. [Sci. Rep. Tôhoku Imp. Univ, IV. (Biol.), 17 (2), (1942), 197 205, 9 Texst-figs.] -- Ten species of freshwater Bryozoa collected in Hokkaido are dealt with in this report

M. Enami.

8. **Studies on Freshwater Bryozoa of Japan. IV. Freshwater Bryozoa of Taiwan (Formosa).** Makoto TORIUMI. [Sci. Rep. Tôhoku Imp. Univ., IV. (Biol.), 17 (2), (1942), 207 214, 3 Text-figs.] — Eight species of freshwater Bryozoa obtained from Taiwan are reported.

M. Enami

9. **On the Nectar-Cropping Activity of an Andrenid, *Halictus katoi* (in Lit.), widely Distributed at Mt. Hakkôda. (Diurnal Rhythm of Activities in Insects and its Environmental Conditions. No. XI.)** Mutsuo KATO. [Sci. Rep. Tôhoku Imp. Univ., IV. (Biol.), 17 (2), (1942), 159-165, 4 Text-figs.] — The nectar-cropping activity of an Andrenid bee, *Halictus katoi*, one of the visitors of the flower of *Lobelia sessilifolia* in the Mt. Hakkôda, Aomori Pref., was studied with the intention to analyze the interrelation between the activity and the environmental meteorological conditions. It was concluded that the activity depends primarily upon the temperature factor in the daytime, though it is affected by the misty rain and by the wind.

M. Enami.

10. **On the Blood Corpuscles and the Blood Formation in *Phoronis*. (The 13th Report of Invertebrate Hematology.)** Toshio OHUYE. [Sci. Rep. Tôhoku Imp. Univ., IV. (Biol.), 17 (2), (1942), 167-185, 17 Text-figs.] — Blood corpuscles of *Phoronis australis* and *P. ijimai* are of following kinds. erythrocytes, hyaline amoebocytes, eosinophilic granulocytes, basophilic granulocytes, cells with Russell bodies, and spindle bodies. With these a histochemical investigation was carried out, in which attention was paid upon the procedures of blood formation during regeneration of lophophores. It was known that the normal hemopoietic manner of *Phoronis* is quite simllar to that of Amphibia, which are deprived of any essential hemopoietic organs.

M. Enami.

11. **On the Blood Corpuscles and the Hemopoiesis of a Nemertean, *Lineus fuscoviridis*, and of a Sipunculus, *Dendrostoma minor*. (The 14th Report of Invertebrate Hematology.)** Toshio OHUYE. [Sci. Rep. Tôhoku Imp. Univ., IV. (Biol.), 17 (2), (1942), 187-196, 7 Text-figs.] — Histochemical study of the blood corpuscles in ***Lineus*** and ***Dendrostoma*** was undertaken wirh the result that the erythrocytes of the former show a good resemblance to those of the Holothurids and the blood corpuscles of the latter resemble closely those of ***Physcosoma***. The hemopoiesis in ***Dendrostoma*** is essentially performed in the endothelium, mesothelium and circulating blood, and there is no specific organ for blood formation.

M. Enami.

12. **Sexual Induction in a Sexually Differentiated Salamander by the Implantation of Testis and Hypophysis.** Tohru UCHIDA and Kin-ichiro HANAOKA. [Journ. Fac. Sci. Hokkaido Imp. Univ., VI. (Zool.), 8 (2), (1942), 75-83, 2 Pls., 4 Text-figs.] — Experiments on the sexual induction in *Hynobius lichenatus* by means of grafting testis alone and of grafting testis together with pituitary gland are reported, results being brought in comparison with those already obtained with *H. retardatus*. In the course of the normal development of the gonad sex-differentiation takes place directly in *H. lichenatus* as early as the larva attains ca. 40 mm of length, such a fact indicating a marked difference from the case in *H. retardatus* in which sex-differentiation is delayed till the stage of metamorphosis. Effect of testis grafting performed in the larva of *H. lichenatus*, ca. 20 mm of length, is expressed as follows: 1) immigration of germ cells to the medulla in the larva, 20-30 mm long; 2) acceleration of sex-differentiation in the larva from the stage of ca. 30 mm long thereafter; 3) elimination of cortical germ cells (especially in the female) in the larva from the operated stage up to the sex-differentiation; 4) acceleration of the development of the male gonad; 5) reduction of the ovarian cavity and partial degeneration of the germ cells, etc. As the result of implantation of both the testis and the pituitary gland in the larva at the stage of neutral gonad, the gonad is affected so as to show figures analogous to those produced by high temperatures M. Enami.

13. **Body-Temperature and Activity of a Moth.** (Japanese.) Dyukiti SIMOIZUMI. [Medicine & Biology, 3 (10), (1943), 328-332, 3 Tabs.] — Motor activity in winter of a moth, *Cocytodes coerulea guénée*, was observed in connexion with its dependence upon the body-temperature and with self-controlling mechanism of the latter. Body temperature was slightly higher than environmental temperature when the animal was at rest. The moth is provided with a mechanism for rise of the body-temperature which is associated with the vibratory motions of the wings, legs and abdominal parts. Of these temperature rise promoted by vibration of the wings was found to be of primary importance. M. Enami

14. **Water-Content of the Blood in relation to Animal Growth.** (Japanese.) Kaitiro KURODA. [Medicine & Biology, 3 (7), (1943), 236-240, 2 Text-figs.] — As the result of a series of investigations concerning the relationship between water-content of the blood and developmental stages in various vertebrates a general rule is formulated. M. Enami.

15. **On the Northern Porpoise Whale, *Berardius bairdii* Stejneger, in the Adjacent Waters of "Bôsyû".** (Japanese with English résumé.) Yoshio MATSUURA. [Zool. Mag. (Tokyo), 54 (12), (1942), 466-473, 7 Text-figs., 4 Tabs.] — Investigations upon *Berardius bairdii* are recorded. M. Enami.

16. **Über die Peristaltik des Regenwurms.** (Japanisch mit Deutschen Resume.) Takao SHIMA. [Zool. Mag. (Tokyo), 54 (12), (1942), 474-482, 5 Text-abbn.] — Auffassung von V. Holst über den Mechanismus der Bewegung beim Regenwurme war kritisiert auf Grund eines Versuches über die lokomotorische Phenomene bei *Eisenia foetida*. M. Enami.

17. **A New Scale Insect from Hainan (Homoptera).** Ryoichi TAKAHASHI. [Zool. Mag. (Tokyo), 54 (12), (1942), 500-501, 1 Text-figs.] — Description of a new scale insect, *Paralecanium hainanense*, n. sp., is given. M. Enami.

18. **Über den Einfluss der β-Strahlen auf die jungen Flügelchen der Schmetterlingspuppen. (Vorläufige Mitteilung.)** Sanji KISHI, Mituo MIWA und Kazuo MORI. [Zool. Mag. (Tokyo), 54 (12), (1942), 502-505, 1 Text-abb., 1 Taf.] — Einwirkung der β-Strahlen emittiert aus der Radium-Emanation auf die jungen Flügelchen der Puppen von *Papilio xuthus*, *P. demetrius* und *P. sarpedon nipponus* war beobachtet. Hauptsächliche Resultate der Bestrahlung waren folgende: 1) Die Faltenbildung; 2) das Fehlen der Beschuppung; 3) die Blasenbildung mit Inhalt von grüner Flüssigkeit; 4) wie eine Verbrennung bildeten sich an den Flügeln hochgrädige Falten; 5) die Asymmetrie, die infolge der oben erwähnten Veränderungen eine unvollkommene Entwicklung der bestrahlten Flügel verursachte. M. Enami.

19. A New Name for the Japanese Blue Magpie. Masauji HACHISUKA. [Zool. Mag. (Tokyo), 54 (12), (1942), 505.] — In accordance with the union of the genus *Cyanopica* to the genus *Pica*, the Japanese blue magpie is to be dealt with under a new name, *Pica cyanus onaga*, nom. nov. M. Enami.

20. On a New Species of Opiliones from the Island of Amami-Ôsima. Kodi NAKATSUDI. [Zool. Mag. (Tokyo), 54 (12), (1942), 503-508, 1 Text-fig.] — Description of a new species of Opiliones collected in the Island of Amami-Ôsima, Riu-Kiu, *Argyraster amamiana*, n. sp., which constitutes a new genus, *Argyraster*, n. gen. M. Enami.

21. Sur l'hôte définitif du *Plagiorchis fuji* Ogata. Toji OGATA. [Zool. Mag. (Tokyo), 54 (10), (1942), 427-430, 2 Figs.] — En cherchant l'hôte définitif naturel d'une espèce de trématode, *Plagiorchis fuji*, qui a été obtenue expérimentalement d'une sorte de métacercaire enkystée dans le coelome du *Stenopsyche griseipennis*, l'auteur a obtenu quelques spécimens de l'intestin grèle du *Rhinolophus ferrum-equinum nippon*, qui manifestent une identité remarquable à l'espèce en question. M. Enami.

22. Die Japanischen Colobognathenarten (Diplopoda). Yosioki TAKAKUWA. [Zool. Mag. (Tokyo), 54 (10), (1942), 424-426, 6 Text-abbn.] — Die Revision der Colobognatha-Arten bisher bekannt aus Japan, mit den Beschreibungen von einer neuen Gattung, *Boninozonium*, n. gen., besteht aus einer Art. *B. Okabei*, n sp., und von einer Art, *Trichozonium okazakii*, n. sp. M. Enami.

23. On the behavior of Nest-Building Habit of *Chironomus*-Larva. (Japanese with English résumé.) Masahiro OHGAKI. [Zool. Mag. (Tokyo), 54 (10), (1942), 375-386, 5 Text-figs., 9 Tabs.] — Nest-building habit of a *Chironomus*-larva was observed under experimental surroundings. M. Enami.

24. An Experimental Study of the Effect of Sludge Volume on the Density of Population of Activated Sludge Organisms. (Japanese.) Isamu HORASAWA. [Zool. Mag. (Tokyo), 54 (10), (1942), 387-391, 3 Text-figs., 4 Tabs.] — Experiments were undertaken with the result that the population density (Pl) of organisms (chiefly protozoan fauna) flourishing in the activated sludge inversely correlates with the sludge volume (Sv) in the relation of $Pl = a \times Sv^{-b}$ under constant amount of total nutriments. M. Enami.

25. Etude sur la variation d'*Oeneis nanna* Ménétriès de Chosen. (Japonais.) D. M. SEOK. [Zool. Mag. (Tokyo), 54 (10), 395-405, 1 Fig., 6 Tabs.] — Variations des caracteres morphologiques d'*Oeneis nanna* obtenu en Chosen sont données avec une note sur la distribution de cette espèce. M. Enami.

26. Mecanisme du Blanchissement de couleur tegumentaire chez *Uca dubia* Stimpson ♀. (Japonais.) Masasi ENAMI. [Medicine & Biology, 2 (4), (1942), 169-172, 3 figs.] — Le blanchissement de couleur tegumentaire d'*Uca dubia* trouvé au bord d'Ile de Korror, Palao, depend à la colaboration de fonction de la glande sinulaire, localisée à la partie distale du sylon oculaire, avec l'activité sécrétoire des organes nerveuses centrales, particulièrement de la ganglion cérébrale. Il a été expérimentalement démontré qu'une certaine principe humorale qui est responsible de la production d'état claire de l'animal, est essentialement élaborée au sein des tissues nerveuses ci-dessus parlées. L'auteur.

27. Mortal Influence of Salinity on Some Cephalopod Larvae. II. (Japanese.) Takaharu YAMAMOTO. [Botany & Zoology, 10 (10), (1942), 908-910, 1 Text-fig., 2 Tabs.] — Tolerance for salinity change in environmental medium was estimated with the larvae of *Octopus vulgaris* and *Loligo bleekeri*. Viability of the larvae of the former species at the stage immediately after hatching was maintained for the salinity range of 30-38‰ (under water temperature of 18.4-23.5°C), and that of the latter for the range of 30-41‰ (under water temperature of 17.1-19.8°C). A short discussion as regards the natural influence of sea water at various waters of Japan upon these cephalopod larvae is rendered. M. Enami.

28. On the Origin of Chromatophores and the Development of Color-Patterns in Amphibians. (Japanese.) Mamoru ITIKAWA. (Botany & Zoology, 10 (11), (1942), 1005–1009.) —A review of literature dealing with the entitled problems. M. Enami.

29. On the Basophile Granules in Cortical Cytoplasm of the Ovum of *Strongylocentrotus pulcherrimus* and their disappearance after fertilization. (Japanese.) Syunzo TAKAGI. [Botany & Zoology, 10 (8), (1942), 719–722, 3 Text-figs.]— The specialized cytoplasmic inclusions in unfertilized ovum of *Strongylocentrotus pulcherrimus*, which were found by Motomura (1936) and were called by him as Janus-green granules, were reexamined in their staining character and their behavior after fertilization. The granules are apparently different from the mitochondria in the staining reactions for dyes, and completely disappear in less than 30 minutes after fertilization of the ovum, while the mitochondria remain unchanged. The granules may better be termed as basophile granules in view of their remarkable affinity to basic dyes which is by no means restricted to Janus-green B as was the case in Motomura's observation
M. Enami.

30. Feeding Habit of *Toxotes jaculator* Pallas. (Japanese.) Nagao ASANO. [Botany & Zoology, 10 (8), (1942), 772–775, 3 Text-figs.]— Ecological notes prepared at the Island of Korror, Palao, on the famous feeding behavior of the archer fish. M. Enami.

31. On the Adaptability of the Japanese Killifish, *Aplocheilus latipes* (Temminck & Schleger), to the Sea Water. (Japanese.) Takaharu YAMAMOTO. [Botany & Zoology, 10 (9), (1942), 805–809, 4 Text-figs., 6 Tabs.]— Natural adaptation to sea water of the Japanese killifish was met with at the coast near Chumunm, Chosen, and this fact led the author to examine the possibility of experimental acclimatization of this fish to higher salinities. It was known that this fish might be transfered from fresh water to sea water without impunity, provided the fish was treated with gradual rise of salinity. M. Enami.

32. Golgi-Apparatus in the Protozoa. (Japanese.) Siro TARAO. [Botany & Zoology, 10 (3), (1942), 260–264, 8 Text-figs.] — A review of literature dealing with the Golgi-apparatus in the Protozoan cells. M. Enami.

33. Experimental Polyspermy in *Strongylocentrotus pulcherrimus* as Induced by the Effect of Neutral Red. (Japanese.) Isao MOTOMURA. [Botany & Zoology, 10 (6), 584, 2 Text figs.]— Polyspermy resulted from a treatment of unfertilized eggs of the sea-urchin, *Strongylocentrotus pulcherrimus*, with neutral red in concentrations of 4 × 10 [illegible], 2 × 10 [illegible], 1 × 10 [illegible], etc. M. Enami.

34. On the Development of the Hard Parts of a Viviparous Ophiuran, *Stegophiura sculpta* (Duncan). Shiro Murakami. [Annot. Zool. Japan., 20 (2), (1941), 67–78, 9 Text-figs.]— Developmental process of the hard parts of *Stegophiura sculpta* abundantly collected off the southern Izu Peninsula was studied. M. Enami.

35. Functions of the Lunules of *Astriclypeus* as Observed in the Righting Movement (Echinoidea). Hayato IKEDA. [Annot. Zool. Japon., 20 (2), (1941), 79–83, 1 Pl., 2 Tabs.]— Locomotive movements and the righting reflex in a Scutellid, *Astriclypeus manni*, were observed with special reference to the function of the ambulacral lunules. It was confirmed that the lunules are of remarkable significance for concealing movement of the animal in the bottom sand and are of particular use for the righting motion. What is responsible for such roles of the lunules was experimentally demonstrated to be vigorous swings of characteristically large spines growing inside the lunules, which act so as to transport rapidly the sand grains through the holes in question. M. Enami.

36. Preliminary Report on *Chorocidaris micca* gen. et sp. nov., from the Ryukyu Islands (Echinoidea, Cidaridae). Hayato IKEDA. [Annot. Zool. Japon., 20 (2), 85–87, 1 Pl.] —Description of a new species, *Chorocidaris micca*, n. sp., which appears to form a new genus. Specimens were collected off the Okinokami-Sima, Ryukyu Islands. M. Enami.

37. Die Opiliones Mikronesiens. Seisyo SUZUKI. [Annot. Zool. Japon., 20 (2), 98–104, 1 Taf., 3 Text-abbn.] — Beschreibungen von 2 Arten, *Paruzalmoxida solitaria* und *Metibalonius esakii*, n. sp., aus der Insel Ponape, Karolinen-Inseln. M. Enami.

38. Ginandromorfo de *Pieris napi* Linné *f. dulcinea* Butler. (Un cas de Gynandromorphisme chez *Pieris napi* Linné *f. dulcinea* Butler.) D. M. SEOK. [Annot. Zool. Japon., 20 (2), (1941), 105, 2 Figs.] — Description d'un individu gynandromorphique du *Pieris napi f. dulcinea* obtenu en Chosen. M. Enami.

39. Notes on Some Chalcidoids from the Micronesian Islands with Descriptions of two new Eucharids. Tei ISHII. [Annot. Zool. Japon., 20 (2), (1941), 106–108, 2 Text-figs.] — Descriptions of following species which were collected in the Micronesian Islands: *Tomocera californica*. *Aphelinus chrysomphali*, *Chalcura upeensis*, *Schizaspidia ponapensis*, n. sp., and *S. palauensis*, n. sp M. Enami.

40. Biting Ceratopogonid Midges from the Caroline Islands. Masaaki TOKUNAGA. [Annot. Zool. Japon., 20 (2), (1941), 109–119, 1 Pl., 13 Text-figs.] — Following species are reported from the Caroline Islands. *Forcipomyia ornata*, *F. sauteri*, *F. fuscimanus*, *Atrichopogon (Kempia) arciforceps*, n. sp., *A. (K.)* sp, *Dasyhelea insularis*, *D. subscutellata*, *D. carolinensis*, n sp., *D. peliliouensis*, *Culicoides esakii*, *C. kusaiensis*, *C. yasumatsui*, n. sp., *C. yoshimurai*, n. sp, *Monohelea insularis*, n. sp, *Stilobezzia subsoror*, n. sp, and *S. longistyla*, n. sp. M. Enami

41. Studies on the Diurnal Rhythm of the Eye Pigments of the Shrimps. (Preliminary Report.) (Japanese with English résumé.) Tametake NAGANO. [Bull. Japan Soc Sci. Fish., 11 (5–6), (1943), 163–167, 4 Text-figs.] — Diurnal rhythm in the migration of the retinal pigments (distal and reflecting ones) of *Leander paucidens*, *Paratya compressa* aud *Spirontocaris alcimede* was observed under continuous illumination and in total darkness. Under both situations rhythmicity was preserved fairly well. Low temperatures appeared to affect the range of migratory movement of the pigments. Concerning the controlling mechanism of the rhythmical phenomenon in question, importance of intermediation of the nervous activity is emphasized. M. Enami.

42. Feeding and Growth of a Japanese Abalone, *Haliotis gigantea discus* Reeve. (Japanese with English résumé.) Takasi INO. [Bull. Japan. Soc. Sci. Fish., 11 (5–6), (1943), 171–174, 2 Text-figs., 2 Tabs.] — With the feeding activity *Haliotis gigantea discus* a remarkable diurnal periodicity was observed, the mollusc being a nocturnal feeder. The animal feeds well during the winter and the spring, but the feeding activity declines as the breeding season (from October to November) approaches. Upon the increase or decrease in the amount of food-consumption depends the growth of body-dimensions. M. Enami.

43. Notes on Frogs of Palao with interesting Habits. (Japanese.) Kenji ATODA. [Kagaku-Nanyo, 5 (2), (1943), 184–193, 3 Pls, 3 Text-figs.] — A preliminary report on the morphology, embryology and ecology of two dimensionally different kinds of frogs widely distributed over the Palao Islands. Both of these frogs (taxonomical study is left untouched) show a much interesting course of development, in which the ordinary aquatic state of tadpoles is completely lacking and a characteristic morphogenesis takes place entirely in the egg which is laid among herbs on the ground, not in water. According to external observations the gill clefts are not formed during such intra-oval development which is deduced to range over ca. 3 weeks, the larval respiration being dependent upon the remarkably swollen abdominal skin highly vascularized; nutrition is supposed to be supplied from the large mass of egg yolk. M. Enami.

44. A Glossary of Local Names of Molluscs in Palao. (Introductory Note in Japanese.) Seiji WADA. [Kagaku-Nanyo, 5 (2), (1943), 225–235.] — A collection of 99 existing local names of economically important Molluscs in the Palao Islands. Special attention is paid to pronunciation of the natives. M. Enami.

45. On the Luminous Organ of *Anomalops katoptron*. (Japanese.) Yata HANEDA. [Kagaku-Nanyo, 5 (2), (1943), 245–252, 7 Text-figs.] — A chance collection at Manokwari, New

Guinea, of specimens of *Anomalops katoptron*, the famous luminous fish in the Banda Sea; enabled the author to investigate the structure and the nature of luminescence of its characteristic infraorbital movable luminous organ. Bacteriological study led the author to an opinion that, contrary to Harvey's and also now prevailing view, the luminescence does not depend upon any symbiotic bacteria but upon the animal's own activity. A short criticism of the nature of luminescence in fishes in general is added. M. Enami

46. Flower of *Fatsia japonica* and Insects, with special Reference to the Importance of Solar Radiant Heat for Insects' Activity. (Japanese.) Mutuo KATO. [Ecol. Rev., 7 (2), (1941), 111-117, 4 Text-figs.] — Motor activity of *Eristalomyia tenax* and *Calliphora lata*, which visit the flower of *Fatsia japonica* from middle November to middle December in Sendai, was observed with respect to its dependence upon the environmental factors. Basal reaction of the insects' activity was concluded to be that of the temperature. Owing to rather insignificant co-operation of the atmospheric temperature during the period of observation, the effect of the solar radiant heat appeared to be of predominant importance. M. Enami.

47. On the Ink-Sac of a Gadid Fish, *Antimora microlepis* Bean. (Japanese.) Kiyomatu MATUBARA and Nagao ASANO. [Journ. Oceanogr. Soc. Japan, 2 (2), (1943), 11-15, 3 Text-figs.] — Macroscopical observation of the large intra-muscular ink-sacs, so-called according to their activity of production and discharge of a sepia-colored fluid, which have respective openings in lateral-line scales in *Antimora microlepis*, a deep-sea Gadid fish. The authors suggest that biologically this ink-producing activity of the fish may have certain protective meaning, the body-surface of the fish being smeared always with the ink. Emergency discharge of the ink cannot be conceivable. M. Enami.

48. Some Informations concerning the Anadromy of *Plecoglossus altivelis*. (Japanese.) Morisaburo TAUTI. [Journ. Oceanogr. Soc. Japan, 2 (1), (1942), 27-28, 1 Text-fig.] — In analyzing statistical data from various sources, effects of the hydrographical as well as the biological factors upon the anadromy of *Plecoglossus altivelis* along the coast of Japan Proper was formulated. M. Enami.

49. Variations in Colors and Patterns in some Holothurians. (Japanese.) Tosihiko YAMANOUTI. [Kagaku-Nanyo, 5 (1), (1942), 74-78, 8 Text-figs.] — Five species of *Holothuria* obtained along the Palao Islands were dealt with as regards the coloration and its ecological bearing. Each species exhibits more or less marked chromatic variation individually, though somewhat clear bilaterality is detectable in the arrangement of the pattern. Abundance in chromatic expression is deduced to be based on highly active metabolism in these animals, and the chromatic bilaterality appears to be of significance in relation to the characteristic bilaterality of organization of Holothurians. M. Enami.

50. Land-Snails collected from the Truk Islands. (Japanese.) Kenji ATODA. [Kagaku-Nanyo, 5 (1), (1942), 128-136, 15 Text-figs.] — From 15 islands of the Truk Group visited by the author in 1940, 16 species (including several undetermined ones) of the land-snails were collected. Notes of ecological interest concerning respective species are added. M. Enami

51. Induction of Spawning of the Scallop, *Pecten* (*patinopecten*) *yessoensis* Jay. (Japanese with English résumé.) Toraitiro KINOSITA, Sangoro SIBUYA and Ziro SIMIZU [Bull. Japan. Soc. Sci. Fish., 11 (5-6), (1943), 168-170, 1 Text-fig.] — Active spawning was induced in *Pecten* (*Patino-*) *yessoensis* as the result of sudden and simultaneous rise of the temperature and alkalinity of environmental sea water. Change in either of these factors was ineffective. M. Enami

52. On the Gonad of the Bonito, *Euthynnus pelamys*, caught near the Palao Islands. (Japanese.) Kizo MATUI. [Kagaku-Nanyo, 5 (1), (1942), 117-122, 4 Text-figs.] — Gonads of 135 individuals of the bonito captured during the period from middle October to early December, 1941, in the Palao waters were examined. Most of them were at considerably advanced state of maturity, but no significant difference was detected in the degree of development between the gonads of the fish in December and those in October, suggesting that the

Palao waters may not be inhabited all the year round by the fish but rather be frequented by the fish with the gonads at similar developmental states. M. Enami.

53. **Foraminifera from Adjacent Waters of Palao Islands.** (Japanese.) Yosine HADA. [Kagaku-Nanyo, 5 (2), (1943), 194-214, 33 Text-figs.] — There are reported in this paper 41 species including 3 new species, exact identification of which being retained for subsequent publication, belonging to the arenaceous Foraminifera collected from the bottom at several localities near the Palao Islands. M. Enami.

54. **Results of the Collection of Fishes from the Japan Sea on Board the ,, Soyô-maru ".** (Japanese with English résumé.) Yasuo SUYEHIRO. [Journ. Imp. Fish. Exp. Stat., 12, (1942), 41-54, 2 Text-figs., 6 Tabs.] — In the course of the 3rd simultaneous hydrographical investigations in the Japan Sea conducted from May to June, 1941, an extended exploration of fish-fauna was realized at various localities over the Sea. As the result, it was found that there are abundant distribution of the sauries (*Cololabis saira*) and the Alaska pollacks (*Theragra chalcogramma*) over somewhat extended area of the Sea, the former being especially abundant in the region influenced by the warn Tusima Current and the latter in the region affected by the cold Riman Current. M. Enami.

55. **Measurement on the Bodily Density, Body-Temperature and Swimming Velocity for " Katuo ", *Euthynnus vagans* (Lesson).** Nobuo WATANABE. [Bull. Japan. Soc. Sci. Fish., 11 (4), (1942), 146-148, 1 Text-fig., 3 Tabs.] — From the observations made in the north-eastern district of Japanese waters it was noted that *Euthynnus vagans* has the bodily density of 1.026-1.038 g/cm^3, and that the body-temperature ranging from 27.6°C up to 28.8°C was higher than the occasional surface temperature of the fishing ground by 2.1-3.4°C. Body-temperature showed a tendency to increase with increase in the body weight. Swimming velocity of the fish estimated during the standstill of the vessel averaged ca. 7.7 m/sec, or, when observed sailing vessel, averaged ca. 6.4 m/sec. M. Enami.

56. **Studies on the Hibernation of the Japanese Dormouse, *Glirulus japonicus* (Schinz). III. Temperature as a Factor for the Hibernation.** (Japanese.) Jyukiti SIMO-IZUMI. [Botany & Zoology, 11 (2), (1943), 125-130, 3 Text-figs., 6 Tabs.] — With the view to examine the possible correlation between the temperature factor in the environment and initiation of the hibernation in the Japanese dormouse, the author planned 4 series of experiments in which feeding together with motor activities of the animal were resorted to as indicators of the phenomenon in question. Animals maintained under experimental temperatures exhibited increasing tendency of hibernating posture as the environmental temperature lowered beyond 16°C. Under the temperature of 12°C and of far lowered grades the phenomenon took place rather decidedly. Such responses were proved to occur regardless of seasons of the year. When transferred in summer to low-temperature locality in the natural environment (ca. 3000 m above the sea-level of Mt. Fuji) where the atmospheric temperature was 10.5-15.1°C (average 12.8°C), the animal that had exhibited no sign of the hibernation in low land (ca. 800 m above the sea-level) under the atmospheric temperature of 19.6-24.8°C (average 21.5°C), fell into the hibernating state, showing the characteristic sequence of the body-temperature. M. Enami.

57. **Daily Periodicity in the Motor Activity of three Actinians.** (Japanese.) Syuiti MORI. [Zool. Mag. (Tokyo), 55 (1), (1943), 1-7, 1 Pl., 4 Text-figs.] — Diurnal rhythm in the motor activity of three Actinians, *Chondractis* sp., *Dofleinia armata* and *Cerianthus misakiensis*, was observed with special consideration of the environmental conditions. Light was found to be the predominant controlling factor for the phenomenon, the rhythmicity in these animals being likely to be the exogenous one. Symbiosis of the Zooxanthellae with the actinians has significant bearing upon the activity of the latter in such manner that *Chondractis* associated with the Zooxanthellae displays the diurnal activity, while *Dofleinia* and *Cerianthus*, both of which lack the Zooxanthellae, are the nocturnal animals. M. Enami.

58. **Rôle of the Prothoracic Gland in Differentiation of the Imaginal Characters in the Silkworm Pupa.** Soichi FUKUDA. [Annot. Zool. Japon., 20 (1), (1941), 9-13, 3 Text-figs., 2 Tabs.] — Humoral control of development of the imaginal characters in the silkworm

pupa was demonstrated The possible source of the endocrine substance responsible for the final metamorphosis of the worm was deduced to be the prothoracic gland M Enami

59. The Retained Sea Water in the Bottom Mud of Brackish Waters and its Influence on the Bottom Inhabitants. (Japanese) F ASAHINA [Ecol Rev, 8 (4), (1942), 221 232, 3 Text figs, 5 Tabs] — Hydrographical observations were made upon the properties of the sea water retained in the bottom mud in 4 brackish lakes in Hokkaido and one in the Simusyu, one of the North Kurile Islands, and the ecological bearing of the results upon the environment inhabited by various kinds of bottom fauna was discussed M Enami

60. Change in the Tolerance against Pressure of the Egg of *Oncorhynchus keta* Walbaum at the Time of Hatching (Japanese Rinzo TANAKA [Zool Mag (Tokyo) 55 (1, (1943, 14 20, 3 Text figs, 5 Tabs] — Assuming that the tolerance of the egg of the salmon *Oncorhynchus keta*, against pressure might parallel to the thickness of the egg membrane the author attempted to elucidate the time relations of liquefying process of the internal egg membrane at the time of hatching Marked fall of the tolerance against pressure was recorded 11 hours prior to hatching although no change in the tolerance was observable at the time 13 hours before hatching Hence the initiation of liquefaction of the internal egg membrane was thought to be approximately 12 hours before hatching Decrease in the tolerance against pressure was especially accelerated from the time 3 hours before hatching on M Enami

61. Eine neue Kocherfliege, *Triaenodes esakii*, von den Palau-Inseln. Matsunae TSUDA [Annot Zool Japon 20 2 1941) 121 122, 2 Textabbn] Beschreibung von einer neuen Art gesammelt an den Palau Inseln M Enami

62 Formation of Lateral Regenerate in *Branchiura sowerbyi* Norio NAKAMURA [Annot Zool Japon 20 (2 (1941, 93 97, 5 Text figs 3 Tabs] — Experimental production of lateral regenerates in a branchiate Oligochaete *Branchiura sowerbyi* is reported It is shown that a lateral head is induced as the result of incisions made on the ventral side of the body at levels higher than the 13th segment, and a lateral tail appears from the operation made at levels lower than the 15th segment Parallelism between the faculty of formation of the lateral regenerates and the differential susceptibility gradients is obviou M Enami

63. Partial Doubling of an Annelid, *Marphysa sanguinea* Montagu Natao YOSII [Annot Zool Japon, 20 (2), (1941), 89 92, 7 Text figs] Morphological study with a case of mesodidymus in *Marphysa sanguinea* is reported M Enami

64. A New Marine Ciliate *Cirrhogaster monilifer* n g n. sp Y OZAKI and R YAGIU [Annot Zool Japon, 21 2 (1942, 79-81 1 Text fig] Description of a new species which forms a new genus of Ciliata The animalcule was obtained from the coast of the Seto Inland Sea M Enami

65. Note on *Cyproniscus ovalis* n. sp., a New Cryptoniscan Parasite (Epicaridea, Isopoda) found on *Cypridina hilgendorfi*. S M Shiino [Annot Zool Japon, 21 2, (1942) 82-89, 4 Text figs, 3 Tabs] - Morphological study on a parasitic Isopoda found in the shell cavity of *Cypridina* occurring in the neighborhood of the Misaki Marine Biological Station The parasite was considered to constitute a new category in the genus *Cyproniscus* M Enami

66. A New Commensal Shrimp, *Spongicola japonica*, n. sp. Ituo KUBO [Annot Zool Japon, 21 (2), (1942), 90 94, 2 Text figs] — A new species of shrimp was found commensal with a deep sea sponge, *Euplectella marshalli* M Enami

67. On the Pupal Diapause of *Sturmia sericariae* (Diptera, Tachinidae), I. Zyuiti KUWANA [Annot Zool Japon, 21 (2), (1942), 95 101, 3 Tabs] – Observations on the period of diapause of a tachinid fly, *Sturmia sericariae*, which severely attacks *Bombyx mori*, were made under natural as well as experimental conditions The emergence of the adult is induced by prolonged effect of low temperatures, the pupal diapause being broken through the effect of 5-12°C for longer than 2 months. Such dependence of completion of the pupal diapause upon the effect of low temperatures may account for the fact that damage of the silkworm cocoon by this fly is not serious in the southern Japan. M. Enami.

68. Two New Genera and Species of Aleyrodidae from Thailand and French Indo-China (Homoptera). Ryoichi TAKAHASHI. [Annot. Zool. Japon., 21 (2), (1942), 102-105, 2 Text-figs.] — Following two new genera each comprising one new species are reported: *Dialeurotrachelus cambodiensis*, n. gen. n. sp., and *Heteraleyrodes bambusae*, n. gen. n. sp.
M. Enami.

69. Notes on the Japanese Fishes of the Genus *Epinephelus*. Shigeo MASUDA. [Annot. Zool. Japon., 21 (2), (1942), 106-123, 1 Pl., 4 Text-figs.] — Fourteen species and 28 forms of the genus *Epinephelus* were dealt with special considerations on their relationship and variability from the view-point of cranial osteology. M. Enami.

70. Behavior of Ovarian Grafts in Hypophysectomized Male Rats with Gonadectomized Parabionts. Evidence for Secretion of Luteinizing Hormone by Male Anterior Hypophysis. Kiyoshi TAKEWAKI and Yasumasa YAMAO. [Annot. Zoo. Japon., 21 (1), (1942), 1-11. Pl.] — In the ovaries subcutaneously implanted in a male rat that had been hypophysectomized or castrated and united in parabiosis with a gonadectomized male or female partner the formation of lutein tissue was decidedly indicated. This fact led the authors to an assumption that the luteinizing hormone might be liberated from the anterior pituitary gland of gonadectomized rats of either sex. Susceptibility of male and female rats with castrated parabionts for the follicle-stimulating and the luteinizing hormones of the anterior pituitary is discussed. M. Enami.

71. Secretion of Luteinizing Hormone by Male Hypophysis. Kiyoshi TAKEWAKI. [Annot. Zool. Japon., 21 (1), (1942), 13-23, 1 Pl.] — It was observed that luteinization took place in ovaries grafted in the ear, at the base of the ear, or in the frontal region, suggesting the secretion of luteinizing hormone by the male anterior pituitary gland. Experiments of transplantation of ovaries at different sites of different body temperatures show that temperature factor does not seriously affect the luteinization. Influence of the uterus transplanted in a male mouse upon co-existing ovarian graft is neglected. M. Enami.

72. The Nervous System in some Coelenterate Types. 2. Ephyra and Scyphula. Taku KOMAI. [Annot. Zool. Japon., 21 (1), (1942), 25-29, 4 Text-figs.] — Nervous organizations in the Ephyra of *Dactylometra pacifica* and *Pelagia panopyra* and the Scyphula of *Aurelia aurita* were analyzed by means of vital staining. M. Enami.

73. On two New Species of Decapoda, Macrura. Ituo KUBO. [Annot. Zool. Japon., 21 (1), (1942), 30-38, 5 Text-figs.] — Descriptions of 2 new species, *Rhynchocinetes uritai*, n. sp., and *Stylodactylus multidentatus*, n. sp. M. Enami.

74. Zur Kenntnis der Japanischen Diplopoden. Yosioki TAKAKUWA. [Annot. Zool. Japon., 21 (1), (1942), 39-47, 16 Text-abbn.] — Eine Sammlung von neu-gefundeten Arten aus Japan. Beschreibungen über den folgenden Arten sind gegeben: *Japonaria terminalis*, n. sp., *J. erythrosoma*, n. sp., *J. attemsi*, *J. acutidens*, *J. spiraligera*, *J. laminata*, *J. kuhlgatzi*, *J. armigera*, *Ezodesmus lunatus*, n. gen. n. sp., *Levizonus circularis*, n. sp., *Haplogonosoma silvestre*, n. sp., *H. s. dichotomum*, n. subsp., *Skleroprotopus laticoxalis*, n. sp., und *S. montanus*, n. sp.
M. Enami.

75. The Fishes of the Genus *Franzia* found in the waters of the Riu-Kiu Islands. Hyozi AOYAGI. [Annot. Zool. Japon., 21 (1), (1942), 48-53, 1 Pl.] — Descriptions of 2 species, *Franzia squamipinnis* and *F. cheirospilos*, both of which were studied on fresh samples obtained near the Okinawa-Honto. M. Enami.

76. A Record of *Anomalops katoptron* (Bleeker) from Japan. Tokiharu ABE. [Annot. Zool. Japon., 21 (1), (1942), 55-57, 1 Text-fig.] — The famous luminous fish that has been known from tropical seas was caught near Kominato, Tiba Pref. External characters of the secured specimen are recorded. M. Enami.

77. The Reversible Asymmetry in the Opercula of *Hydroides ezoensis*. I. Observations on the Intact Opercula. Atsuhiko ICHIKAWA and Narihiko TAKAGAKI. [Journ. Fac. Sci. Hokkaido Imp. Univ., VI. (Zool.), 8 (1), (1942), 1–8, 1 Text-fig., 3 Tabs.] — Examination of a number of specimens of a Serpulid, *Hydroides ezoensis*, with regards to relative positions of the functional operculum resulted in a view that a process is operating in this worm in nature so as to reverse the morphological as well as functional asymmetry in the opercula. Reversal in the arrangement of opercula was observed under the laboratory condition too. The phenomenon seems to take place in the fall of the year. M. Enami.

78. On the Nature of Cytoplasmic Constituents in *Amoeba diploidea* Examined by means of Staining and Chemical Reactions. Sirô TARAO. [Journ. Fac. Sci. Hokkaido Imp Univ., VI. (Zool.), 8 (1), (1942), 9–30, 1 Pl., 4 Text-figs., 3 Tabs.] — There are reported various histochemical investigations upon the cytoplasmic constituents of *Amoeba diploidea* obtained from the faeces of the rabbit. M. Enami.

79. Studies on the Murine Chromosomes. II. Morphological Comparison of the Chromosomes between the Wild Form and the Domesticated Variety of *Rattus norvegicus* Berkenhout. Sajiro MAKINO. [Journ. Fac. Sci. Hokkaido Imp. Univ., VI. (Zool.), 8 (1), (1942), 31–43, 30 Text-figs., 1 Tab.] — Morphological analysis of the chromosomes of the wild form of *Rattus norvegicus* and of the domesticated albino rat was undertaken with the view to gain accurate informations concerning the extent of morphological similarity among the corresponding elements of chromosomes in respective kinds of rats. As the result of a serie of detailed examinations it was found that there is no visible difference in the chromosomal elements between these kinds of rats, remarkable identity existing not only in the chromosome number but also in the external features of individual elements. M. Enami.

80. The Rats and Mice of Formosa, Illustrated. Bunichirô AOKI and Ryô TANAKA. [Mem. Fac. Sci. Agr. Taihoku Imp. Univ., 23 (4), (1941), 121–191, 13 Pls., 26 Text-figs.] — A monograph dealing with 13 species of Muridae hitherto determined from Formosa. Description of each species is accompanied by a beautiful color plate showing the habitat and characteristic behavior of respective animal. M. Enami.

81. Hemerythrin found in the Blood of *Lingula*. Siro KAWAGUTI. [Mem. Fac. Sci Agr. Taihoku Imp. Univ., 23 (3), (1941), 95–98.] — It was found that red blood cells of *Lingula unguis* L. contain hemerythrin which is easily reduced to a colorless form, regaining reddish-purple color by oxygenation. The redox potential of half-reduced hemerythrin of *Lingula* is $E_0 = 0.160$ volt at pH 6.8, 21°C. This pigment is closely allied to hemerythrin found in *Sipunculus* and *Phascolosoma* in its chemical reactions as well as general features of the spectrograms.
M. Enami.

82. Electrolytes in *Paramecium*. Yasukazu AKITA. [Mem. Fac. Sci. Agr. Taihoku Imp. Univ., 23 (3), (1941), 99–119, 3 Text-figs., 4 Tabs.] — Investigations were made upon the behavior of principal inorganic elements (Na, K, Ca and Cl) through the cell membrane of *Paramecium caudatum* with the conclusion that the cell membrane of this animalcule is permeable to cations but not to anions. M. Enami.

83. Ecology of the Vaginula, *Meisenheimeria alte* Férussac, with some experiments on dessication. Echio ISHIGURO. (With a Memorial Note by K. Hirasaka.) [Mem. Fac. Sci. Agr. Taihoku Imp. Univ., 23 (5), (1942), 181–210, 10 Text-figs., 6 Tabs.] — The Vaginula, *Meisenheimeria alte*, which is found in gardens and garbage bins at Taihoku was studied from the ecological point of view. Its biology is elucidated in many respects, viz. breeding, growth, locomotion, diurnal rhythm of activity, reaction and homing habit, feeding habit, resistance to dessication, etc. M. Enami.

84. On an Asymmetrically Colored American Lobster. Naohide YATSU. [Annot. Zool. Japon., 20 (1), (1941), 1–3, 1 Text-fig.] — A female specimen of the American lobster showing a remarkable particoloration in the cephalothorax is described with remarks to other cases of asymmetrical coloration hitherto reported in lobsters and a crayfish. M. Enami.

85. **Effect of Gonadectomy and Hypophysectomy on the Kidney and Genital Tract of a Snake, *Natrix tigrina tigrina*.** Kiyoshi TAKEWAKI and Kozi HATTA. [Annot. Zool. Japon., 20 (1), (1941), 4-8, 9 Text-figs.] — Modifications elicited in histological features of the kidney and genital tract were examined as the effect of gonadectomy and hypophysectomy executed upon *Natrix tigrina tigrina*. M. Enami.

86. **A Preliminary Note on the Glochidia of Japanese Freshwater Mussels.** Samakiti INABA. [Annot. Zool. Japon., 20 (1), (1941), 14-23, 2 Pls., 6 Text-figs.] — Glochidia of 22 species of the Unionid mussels of Japan are dealt with. They are classified into 2 well-marked morphological types, viz. *Anodonta* type and *Lampsilis* type. A key for identification of the Glochidia is given. M. Enami.

87. **A New Primitive Hypotrichous Ciliate, *Kiitricha marina*, n. g. n. sp.** Kanefumi NOZAWA. [Annot. Zool. Japon., 20 (1), (1941), 24-26, 3 Text-figs.] — Note on a ciliate obtained from a sea-weed infusion is given. The animalcule is provided with some primitive charecters of the category of Hypotricha, and is designated to be a new form constituting a new genus. M. Enami.

88. **Two New Trematodes of *Cephalogonimus* from *Amyda*.** Yosio OGURO. [Annot. Zool. Japon., 20 (1), (1941), 27-32, 5 Text-figs.] — Descriptions of 2 new species of the genus *Cephalogonimus*, *C. parvus*, n. sp., and *C. manchuricus*, n. sp., both of which are intestinal parasites of the mud turtle, *Amyda sinensis*. M. Enami.

89. **A New *Chionaspis* from Corea (Homoptera, Coccidae).** Sigeo KANDA. [Annot. Zool. Japon., 20 (1), (1941), 33-35, 1 Pl.] — Description of a new species, *Chionaspis nishikigi*, n. sp. M. Enami

90. **Nouvelles Espèces de Scarabaeides du Manchoukuo et de la Corée.** Jozo MURAYAMA. [Annot. Zool. Japon., 20 (1), (1941), 36-40.] — Cinq nouvelles espèces de Scarabaeides, *Sericania latisulcata*, n. sp., *S. hasegawai*, n. sp., *Lasiopsis manchuricus*, n. sp., *L. balgensis*, n. sp., et *Holotrichia reticulata*, n. sp., sont proposées. M. Enami.

91. **The Fishes of the Family Pseudochromidae found in the Waters of the Riû-Kiû Islands and the Palau Islands.** Hyôzi AOYAGI. [Annot. Zool. Japon., 20 (1), (1941), 41-54, 1 Pl., 5 Text-figs.] — Thirteen species of the family Pseudochromidae including one new species, *Pseudochromis kikaii*, n. sp., are reported with a key for identification of Japanese species. M. Enami.

92. **Studies on the Scorpaenoid Fishes of Japan. Anatomy, Phylogeny and Taxonomy (I).** Kiyomatsu MATSUBARA. [Trans. Sigenkagaku Kenkyusyo, 1, (1943), 1-170, 4 Pls., 156 Text-figs.] — Extended studies of anatomy and biometry in the Japanese Scorpaenoid fishes made the author to establish a new system of classification for the group, a single family Scorpaenidae, comprizing 14 subfamilies, 33 genera, 10 subgenera, 78 species, 1 subspecies and 7 formae. The new classification is primarily based upon the internal features, being unlike the former ones which are mostly based upon the external character. Descriptions of following new species, new subspecies and new formae are included in this paper: *Sebastes* (*Mebarus*) *paradoxus*, n. sp., *S.* (*Acutomentum*) *paucispinosus*, n. sp., *Scorpaena hatizyoensis*, n. sp., *Ocosia fasciata*, n. sp., *Cocotropus masudai*, n. sp., *Neocentropogon aeglefinnus*, *japonicus*, n. sp., *Sebastes* (*Murasoius*) *pachycephalus f. nudus*, n. form., and *S.* (*M.*) *p. f. chalcogrammus*, n. form. Systematic significance of the suborbital bones, the suspensorium and opercular apparatus, the hyoid apparatus, the cranium, the vertebrae, the shoulder girdle, the pelvic girdle, the air-bladder, the alimentary canal and pyloric coeca is respectively discussed. A phylogenetical consideration is also given. M. Enami.

93. **Rhizocephala of Japan.** Sueo M. SHIINO. [Journ Sigenkagaku Kenkyusyo, 1 (1), (1943), 1-36, 24 Text-figs.] — Descriptions of 24 species including 12 new species, *Peltogaster lineatus*, n. sp., *P. reticulatus*, n. sp., *Sacculina cordata*, n. sp., *S. imberbis*, n. sp., *S. pinnotherae*, n. sp., *S. nigra*, n. sp., *S. fabacea*, n. sp., *S. pugettiae*, n. sp., *S. upogebiae*, n. sp., *Loxothylacus*

tomentosus, n sp, *Heterosaccus setoensis*, n sp, and *H pellucidus*, n sp The host parasite interrelation was especially taken into account. M Enami

94. Ichthyological Annotations from the Depth of the Sea of Japan, I-VII Kiyomatsu MATSUBARA [Journ Sigenkagaku Kenkyusyo, 1 (1), (1943), 37 81 1 Pl 24 Text figs 2 Tabs] Miscellaneous notices on the deep sea fishes collected from the Sea of Japan This series of reports contains 14 species belonging to following genera *Leptoclinus Itatius* n gen, *Bythites, Homostolus, Glyptophidium Neoscopelus, Argentina, Leuroglossus Yarrella* and *Astronesthes* Following new species are reported *Leptoclinus triocellatus* n sp, *Itatius microlepis* n gen n sp, *Homostolus japonica* n sp *Neoscopelus microchir* n sp *Leuroglossus lineatus* n sp and *Yarrella surugaensis*, n sp M Enami

95. On a New Serranid Fish, *Malakichthys elegans* from Suruga Bay, with Special Reference to a Comparison of Hitherto Known Species. Kiyomatsu MATSUBARA and Masao YAMAGUTI [Journ Sigenkagaku Kenkyusyo 1 (1) (1943 83 96 5 Text figs 3 Tabs] Description of a new species of the genus *Malakichthys*, *M elegans*, n sp collected off Heta Izu Peninsula, with some remarks from biometrical standpoint as regards the diversity of the present species from *M griseus* and *M wakiyae* M Enami

96. Studies on the Striped-Mouse of Manchoukuo. Japanese M TOKUDA [Misc Rep Sigenkagaku Kenkyusyo 1 (1943), 1 22, 11 Text figs] This paper was prepared with the intention to teach some methods for investigation of small Mammals in taxonomical, morphological and ecological fields referring to the cases in the striped mouse *Apodemus agrarius* widely and commonly inhabiting Manchoukuo Concretely described accounts of practical use M Enami

97. Foraminiferan Fauna of Philippine Waters as Considered in Relation to Environmental Conditions. (Japanese), Reiko IISIJIMA Masaho MARUBASI and Umeka KITAZAKI [Misc Rep Sigenkagaku Kenkyusyo, 1, (1943), 23-40 2 Pls 5 Text figs, 1 Tab] Analyzing the data afforded by Cushman's paper (Cushman J A 1921 U S Nat Mus Bull 100), the writers coarsely outlined the vertical distribution of Foraminifera in the Philippine waters M Enami

98. A Catalogue of Mollusca from the Suruga Bay. (Japanese Katsura OYAMA [Misc Rep Sigenkagaku Kenkyusyo 2 1943), 3 47 2 Text figs] 611 species including 35 undetermined ones of mollusca obtained from the Suruga Bay are listed M Enami

99. Contributions to the Classification of the Sea-Stars of Japan. II Forcipulata, with the Note on the Relationships between the Skeletal Structure and Respiratory Organs of the Sea-Stars. Ryoji HAYASHI [Journ Fac Sci Hokkaido Imp Univ VI Zool 8 (3), (1943, 133 281, 11 Pls, 115 Text figs] Systematic study upon Japanese materials of the order Forcipulata which consists of Brisingidae Zoroasteridae and Asteriidae Description of 41 kinds including following new species and new forms *Odinia pacifica* form *sagamiana* n, form, *O austini* form *japonica*, n form, *Parabrisinga pellucida* n sp *Freyellaster fecundus* form *ochotensis*, n form, *F intermedius*, n sp, *Zoroaster orientalis*, n sp *Z o* n sp form *gracilis*, n form, *Pedicellaster magister esoensis*, n subsp, *Fiasterias echinosoma* form *robusta* n form, *Leptasterias orientalis aniwaensis*, n subsp, *L pulchella*, n sp, and *L p* n sp, form *tugaruensis* n form. In additional notes are dealt with some morphological findings worked out with 114 species of the sea stars, which show more or less significant bearing of the Polian vesicles and the ampullae of the tube feet for the respiratory organization of this group of animals
M Enami

100. The Fauna of Akkeshi Bay. XIII. Caprellidae. Huzio UTINOMI [Journ Fac. Sci. Hokkaido Imp Univ, VI (Zool), 8 (3), (1943), 283-300, 11 Text-figs] – Eleven species of the genus *Caprella* including 3 new species, *C. aino*, n sp, *C obtusifrons*, n sp., and *C venusta*, n. sp, are recorded from Akkeshi, Muroran and Osyoro, all in Hokkaido A note on the geographical distribution of caprellids is added M Enami

101. A New Species of Archiannelida, *Trilobodrilus nipponicus*, n. sp. Tohru UCHIDA and Shiro OKUDA [Journ. Fac. Sci Hokkaido Imp Univ, VI (Zool), 8 (3), (1943), 301 305, 2 Text figs]—A new form of Archiannelida was found at Akkeshi, Hokkaido It bears characteristic features of the genus *Trilobodrilus*, being distinguished from *T heideri*, the single species hitherto representing the genus, in the presence of a solitary dorsal spine and of ciliary bands on the thoracic segments and especially in the form of the pygidium M Enami

102. Effect of Diets on Maturation of *Plecoglossus altivelis*. (Japanese) T HANAOKA [Fish Invest Suppl Rep, 9, (1943), 52 55, 7 Tabs]—Degree of maturity in *Plecoglossus altivelis* was demonstrated to be considerably enhanced by culturing the fish with diets in which finely macerated carrot was added as a source of vitamine A M Enami

103. Cod Fish as Insulin Source. (Japanese with English resume) M MIGITA [Journ Imp Fish Exp Stat, 13, (1943), 1-23, 2 Text figs, 9 Tabs] A series of investigations focussing the utility of the islet tissue of the cod as the source of insulin was undertaken Broadly speaking, approximately 8 gr of the islet tissue may be obtainable from 100 fresh fish, and average yield of insulin per fish is estimated to be 20 IU M Enami

104. Stimulative Effect of Temperature on the Heart Beat in the Oyster, *Ostrea circumpicta*. Kizo MATSUI [Sci Rep. Tokyo Bunrika Daigaku, B, 5 (86), 295 312, 10 Text figs] Response and accomodation of pulsation of the heart of *Ostrea circumpicta* to sudden increments of temperature were investigated Tests were made on one side upon the heart as a whole as well as upon isolated auricle and ventricle and on the other side upon fragments of respective parts, and there comes the result that the frequency of pulsation increased rapidly at first in response to sudden raise of temperature and decreased subsequently to a constant value and, when temperature was lowered, it decreased rapidly at first, but regaining successively larger values till it attained a constant one Such phenomenon took place more quickly when the temperature change was more rapid In a reverse situation against the change in frequency stood the change in amplitude of the heart beat These experimental results were discussed in comparison with Belehrádek's acquisitions M Enami

105. Temperature and Heart Beat in a Fish Embryo, *Oryzias latipes*. II. The Variation of Heart Rate and Temperature Coefficient caused by Incubation Temperature. Kizo MATSUI [Sci Rep Tokyo Bunrika Daigaku, B, 5 (87), 313-324, 2 Text-figs, 3 Tabs]—*Oryzias* embryo that had experienced a high temperature (29 C) during its developmental course from the egg was at different stages subjected to gradual raising or lowering of environmental temperature, and the mode of response to such treatments of the pulsatory movement of the heart was observed Results were compared with those in the embryo incubated at a lower temperature (17°C) In the embryo incubated at 29 C the temperature coefficient showed considerable variation according to difference in developmental stage, and some irregular heart beats took place in earlier stages, which were assumed to be due to decreased resistance of the embryo to chilling Besides, the heart rate in such embryo was smaller as compared with that in the embryo incubated at 17 C M Enami

106. Temperature and Heart Beat in a Fish Embryo, *Oryzias latipes*. III. Heart Beat of the Developing Embryo at a Constant Temperature. Kizo MATSUI. [Sci Rep Tokyo Bunrika Daigaku, B, 5 (88), 325-346, 8 Text-figs, 5 Tabs]—Measurements were made on the heart rate at successive stages of development of *Oryzias* embryo which was incubated in one of 7 series of thermostats of constant temperatures, viz. 17°C, 19°C, 21°C, 23°C, 25 C, 27°C and 29°C. Relation between the heart rate and the developmental time may be expressed by the equation $x=A+ae^{-kt}$ (x-heart rate, A maximum frequency, a difference between the maximum and minimum frequencies, k-constant at a given temperature, t developmental time), which indicates that the relation may be interpreted upon the basis of a monomolecular reaction. The sum of the total heart beats from the initiation of pulsation till the time of hatching of the embryo may be calculated by $S=At-\frac{a}{k}$, a derivation obtained from the above equation. It increased as the incubation temperature was lowered M. Enami

107. The Structure and Development of the Sessile Ctenophore *Lyrocteis imperatoris* Komai. [Mem. Coll. Sci. Kyoto Imp. Univ., B, 17 (1), (1942), 1-36, 3 Pls. 27 Text-figs.] — Discovery of a new sessile Ctenophore from a depth of ca. 70 m in the Sagami Sea was already reported by the author in the Proc. Imp. Acad. Tokyo, 17 (1941), 216-220. The present paper, gives full accounts of his extended investigation as regards the morphology, histology and principal events in the developmental course of this very interesting animal which is now represented by 11 specimens preserved either perfectly or but in fragments. As for the systematic position of this Ctenophore the author is of opinion that it may be ranked between *Coeloplana* and *Tjalfiella*, of which the former is more closely approached by the present animal than the latter. Attention is called for an old record of the capture of this animal by Nishikawa (Zool. Mag. (Tokyo), 8 (1896), 307-309.). Beautiful color plates worked out by Sanada, one of the staffs of the Biological Laboratory in the Imperial Palace, who contributed valuable informations of fresh materials of the animal. M. Enami.

108. On the Parasitic Isopoda of the Family Entoniscidae, Especially those Found in the Vicinity of Seto. Sueo M. SHIINO. [Mem. Coll. Sci. Kyoto Imp. Univ., B, 17 (1), (1942), 37-76, 15 Text-figs., 2 Tabs.] — Seven new species of the Entoniscids parasitic to the littoral crabs near the Seto Marine Biological Laboratory are described in detail. *Entoniscus japonicus*, n sp., *Portunion flavidus*, n. sp., *Pinnotherion setoensis*, n. sp, *Cancrion deltoides*, n. sp, *Xanthion spadix*, n. gen. n. sp., *Tiarinion fulvus*, n. gen. n. sp., *Micippion asymmetricus*, n. gen. n. sp. M. Enami.

109. Studies on the Embryology of *Squilla oratoria* De Haan. Sueo M. SHIINO. [Mem. Coll. Sci. Kyoto Imp. Univ., B, 17 (1), (1942), 77-174, 11 Pls.] — In the continuation of Komai's work on the same subject which was limited to the external changes in the developmental course, the present study aimed primarily the elucidation of the internal changes in the course of the entire embryonic life of the animal. Detailed observations initiated at the segmentation of egg and completed at the stage just prior to hatching were followed step by step with the differentiation of germ layers and the formation of organ systems. M. Enami.

110. Studies on the Double Monsters in the Newt, *Triturus pyrrhogaster*, with Special Reference to the Origin of their Development. Mamori ICHIKAWA. [Mem. Coll. Kyoto Imp. Univ., B. 17 (1), (1942), 175-226, 34 Text-figs] - Morphological analysis of 34 cases of double monsters in the Japanese newt, *Triturus pyrrhogaster*, revealed that the possible disturbance responsible for such monstrosity is the physiological or potential isolation of the organiser. Various types of double monsters may be explained on the assumption of diversion of the organiser in different degrees and modes. Significant features of the visceral organs in the double monsters are described and the underlying mechanism is brought into consideration

M Enami.

111. Zur Kenntnis der Koreanischen Trichopteren. Matsunae TSUDA. [Mem Coll. Sci. Kyoto Imp. Univ., B, 17 (1), (1942), 227-237, 12 Text-abbn.] — Fünfzehn Arten von der Trichopteren-Fauna Koreas sind beschrieben. Geschilderte neue Gattung und Arten sind folgende: *Uenotrichia fasciata*, n. gen. n. sp., *Psychomyiella coreana*, n sp., *Molanna coreana*, n. sp, *Leptocerus shuotsuensis*, n. sp., *Setodes uenoi*, n. sp., und *Lithax yamamotoi*, n. sp. M. Enami.

112. Japanische Trichopteren. I. Systematik. Matsunae TSUDA. [Mem. Coll. Sci. Kyoto Imp. Univ., B, 17 (1), (1942), 239 339, 77 Text-abbn.] — Monographie der Japanischen Trichopteren bisher bekannt. 194 Arten von 16 Familien sind bearbeitet mit den Beschreibungen über 43 neuen Arten. M. Enami,

113. The pH and Temperature of the West Lake and of a Habitat of Freshwater Medusae. (Japanese.) Gunji TOMITA. [Shanghai Sizenkagaku Kenkyusyo Ihô. 12 (2), (1942), 167 173, 2 Text-figs., 5 Tabs.] — It was already reported by the author that a remarkable habitat of the fresh-water medusae is located in an islet in the West Lake, Central China, but the Lake water itself is not yet known to be resourceful of the animals. A hydrographical study was then undertaken to explain this curious fact upon the basis of difference in environmental conditions probably existing between the water in the islet and that of the Lake. Both the water temperature and the atmospheric temperature in the Lake are considerably higher than those in the habitat of medusae, and the pH value in the former is much higher than that in the latter. Difference in the pH value between these regions may for the most part be interpreted by the difference in the amount of solar radiation which controls the rate of photosynthesis of plants as well as the animal respiration and decomposition of detritous matters. M. Enami.

114. Systematic Study on the Culicini in Tokyo. (Japanese.) Tamotsu ISIHARA. [Ôyô-Dôbutsugaku-Zassi, 14 (1–2), (1942), 1-22, 14 Text-figs.]—Eight species of mosquitos in the city of Tokyo and its neighboring regions, *Culex* (*Culex*) *pipiens pallens*, *C.* (*C.*) *tritaeniorhynchus*, *C.* (*Lutzia*) *vorax*, *Aëdes* (*Aëdimorphus*) *vexans nipponii*, *A.* (*Finlaya*) *togoi*, *A.* (*F.*) *japonicus*, *A.* (*Stegomyia*) *albopictus*, *Armigeres* (*Armigeres*) *obturbans*, may be identified by the egg shape, larva and pupa. M. Enami.

115. The Fauna of Acid Stream in Japan. I. (Japanese.) Yosiiti KASAI. [Jap. Journ. Limnol., 12 (1), (1942), 14–21, 1 Text-fig., 4 Tabs.]—Seasonal and regional variations in the fauna found in 13 acid streams ($\text{pH}<5.0$) in north-eastern and southern Japan Proper were investigated with special reference to the correlation between apparition of animals and the pH value of surrounding water. It is stated that 28 species of animals occur in the investigated streams, abundance of them being in the order of Coleoptera>Trichoptera>Diptera>Heteroptera>Plecoptera>Neuroptera>Ephemeroptera. M. Enami.

116. On a Benthosic Animal, *Chaoborus* larva, in the Lake Timikeppu, Hokkaido. (Japanese.) Motohiro SAKURAI, Kiyoe SAKAI and Heizo MIHARU. [Journ. Fish. (Hakodate), 50, (1942), 50-60, 5 Text-figs., 9 Tabs.]—*Chaoborus* larvae are the important food for *Salmo nerka* in the Lake Timikeppu, the significance of the animals being predominating during Aug.-Nov. and in Mar. of the year. This paper gives some informations concerning ecological features of the animals in Sept., Dec., and Mar. M. Enami.

117. Medusae and Polyps of *Craspedacusta* in Hangchow, China. (Japanese.) Gunji TOMITA. [Shanghai Sizenkagaku Kenkyusyo Ihô, 12 (1942), 77-86, 2 Pls., 4 Text-figs., 3 Tabs.]—Occurrence of a fresh-water medusa in a small pond in an islet in the West Lake, Central China, has been known from the time as early as 1925, and the animal has been variously investigated since that time. Present report announces finding of the polyp of this medusa, being the first discovery in Asia of the polyp of fresh-water medusa from natural surroundings. Hydrographical study concerning the habitat of this medusa and field observations on the seasonal change of occurrence of the animal are described. M. Enami.

118. Occurrence of Fresh-Water Medusae in Soochow, China. (Japanese.) Gunji TOMITA [Shanghai Sizenkagaku Kenkyu-syo Ihô, 12 (1), (1942), 87-91, 1 Pl., 1 Tab.]—A species of fresh-water medusae belonging to the genus *Craspedacusta* was found by a Japanese inhabitant in 1941 in a small pond at the summit of a hill near Soochow, Central China. A field work was done by the author as regards the ecological conditions of the habitat.
M. Enami.

119. Ecological Studies on *Semisulcospira* (*Cancellata*) *amurensis* (Gerstfeldt). (Japanese.) Noboru ABE. [Res. Bull. High. Norm. Coll. Manchoukuo, 1, (1940), 19–40, 12 Text-figs., 6 Tabs.]—Ecological features of the habitat of *Semisulcospira*, locomotive movements of the shell under natural conditions and factors concerned with the apical erosion of the shell were analyzed. The animal is reported to be positively rheotactic in the rapid flow in summer and in autumn, and to migrate from tributaries into main stream of rivers in the fall. This seasonal migration appears to be not dependent upon the rheo-, thermo-, chemotropisms, etc., but mainly due to reaction of the animal against water pressure, which makes the animal to select a constant depth of water. Breeding is observable throughout summer and autumn, but may probably come to stop towards the end of autumn. Degree of the apical erosion of the shell appears to be parallel to the amount of Fe-content of environmental water.
M. Enami.

120. Notes on the Finger-Like Pectoral Fins in three Japanese Fishes. Mituo SATÔ. [Sci. Rep. Tôhoku Imp. Univ., IV. (Biol.), 17 (1), (1942), 1–8, 6 Text-figs.]—The finger-shaped pectoral fins in *Lepidotrigla strauchi*, *Apistus evolans* and *Inimicus japonicus* were studied histologically as well as from the view point of sensory physiology. The organs in the first named fish are provided with a kind of specialized chemoreceptors in the epidermis, and seems to play some significant role in the search for food buried in the bottom sand. Unlike *Lepidotrigla* the other two species lack the chemoreceptive organization in their modified pectoral fins which appear to be of no use for the location of hidden food. M. Enami

121. Calcareous Sponges Collected in the Kanto District, Japan. Senji TANITA [Sci. Rep. Tôhoku Imp. Univ., IV (Biol.) 17 (1), 17-68, 3 Pl. 13 Text-figs.] Forty species of Calcarea collected at various parts of the Kanto District are reported. Following 11 new species are included, *Leucosolenia izuensis*, n. sp., *L. serica*, n. sp., *Sycon album* n. sp., *S. cylindricum* n. sp., *S. luteolum*, n. sp., *Grantessa parva*, n. sp., *G. shimoda*, n. sp., *Leucandra hozawai* n. sp., *L. impigra*, n. sp., *L. magna*, n. sp., *L. nakamurai*, n. sp., *L. sola* n. sp. and *Leucilla hirsuta* n. sp.
M. Enami

122. Key to All the Described Species of the Genus *Leucosolenia* and their Distribution. Senji TANITA [Sci. Rep. Tôhoku Imp. Univ. IV (Biol.) 17 (1), 1942) 71-93] — 110 known species of Calcarea belonging to the genus *Leucosolenia* are arranged according to the morphological features of spicules, the informations having been collected from a study of literature. The genus is divided into 2 sections according to the presence or absence of oxea, and each section is further divided into 3 groups according to the types of spicules. Localities of respective species are summarized in a review of distribution of the genus in the world.
M. Enami

123. Physiological Studies on the Pigmentary System of Crustacea. I. The Color Change of a Shrimp *Paratya compressa* (de Haan). Tanetake NAGANO [Sci. Rep. Tôhoku Imp. Univ. IV (Biol.) 17 (3), 1943) 223-245, 8 Text-figs., 5 Tabs.] The pigmentary behavior in *Paratya compressa* was observed and analyzed. Various experiments were designed to outline the whole scope of the activity of color changes in this shrimp. Background responses, chromatic reactions under experimental surroundings, and humoral mechanism concerned with the chromatophoral activities were considered. The presence of endocrine mechanism at the rostral part, which was proposed by Koller, was not confirmed. Interspecificity of the eye-stalk principle was obvious. M. Enami

124. Studies on Freshwater Bryozoa of Japan. V. The Variations Occurring in the Statoblasts and in the Number of Tentacles of *Cristatella mucedo* Cuvier. Makoto TORIUMI [Sci. Rep. Tohoku Imp. Univ. IV (Biol.), 17 (3), 1943) 247-263, 6 Text-figs. 5 Tabs.] Morphological variations in a species of Bryozoa collected in the Tohoku and Tyubu districts were examined. M. Enami

125. Caprellids Obtained in Onagawa Bay, Northern Japan. Huzio UTINOMI [Sci. Rep. Tôhoku Imp. Univ., IV (Biol.) 17 (3), (1943) 271-279, 6 Text-figs.] Seven species including a new one, *Caprella imai*, n. sp., are recorded from the Onagawa Bay near Sendai.
M. Enami

126. Report of the Biological Survey of Mutu Bay. 37. Caprellids from Asamusi. Huzio UTINOMI [Sci. Rep. Tôhoku Imp. Univ., IV (Biol.) 17 (3), (1943) 281-287, 6 Text-figs.] — Seven species including a new one, *Caprella venusta*, n. sp., were obtained from Asamusi, Aomori Pref. M. Enami

127. Studies on the Crab-Shaped Anomura of Nippon and Adjacent Waters. Sadayoshi MIYAKE [Journ. Dept. Agr. Kyusyu Imp. Univ., 7 (3), 1943) 49-158, 62 Text-figs., 3 Tabs.] — Detailed investigation upon 36 species of Porcellanidae of Japan and its neighboring regions with some zoogeographical and ecological considerations. A new species, *Petrolisthes masakii*, n. sp., is introduced by this report. M. Enami

128. Studies on the Decapod Crustaceans of Micronesia. III. Porcellanidae. Sadayoshi MIYAKE [Palao Trop. Biol. Stat. Stud., 2 (3), (1942), 329-379, 1 Pl., 15 Text-figs.] — Fourteen species including 2 new species, *Porcellana murakamii* n. sp., and *P. melissa*, n. sp., of the family Porcellanidae are described. Materials were secured from various parts of the Micronesian Islands. M. Enami

129. On the Migration of Calcium during the Moulting in Several Crustaceans. (Japanese with English resume.) Haruo NUMANOI [Bull. Sigenkagaku Kenkyusyo, 1 (1), 1943), 1–25, 4 Text figs., 24 Tabs.] — The mobilization of the calcium compounds during ecdysis in 2 decapods, *Sesarma haematocheir* and *S. dehaani*, and an Isopod, *Ligia exotica*, was investigated with special reference to calcium storing and the biochemical basis for the calcium migration. The first named crab shows formation of the gastrolith as a special reservoir of calcium, the second one makes use of the hepatopancreas as a reservoir and the last animal lacks any specially differentiated structures responsible for storage of calcium, alternate casting of the exuviae performing the function in it. In connection with dissolution into the blood of calcium restored in such reservoirs or in the carapace, the pH value of the blood and various tissue extracts was examined. For the mobilization of calcium the carbonic anhydrase is considered to play a significant part, the enzyme being assumed to be distributed in the order of hepatopancreas, blood, gonad, gill, digestive tract, muscle, carapace. M. Enami.

130. Significance of the Animal's Proper Pituitary Gland in Experimental Induction of Ovulation in *Onychodactylus japonicus* (Houttuyn). (Japanese.) Dyohati NAKAMURA [Zool. Mag. (Tokyo), 54 (1), 1942), 1–10, 2 Text figs., 8 Tabs.] The author assumed from his foregoing experiments that the cessation of ovulation in *Onychodactylus* in captivity might probably due to inactivated state of the hormone of the anterior lobe of the pituitary and not to quantitative decrease in the hormone under artificial surroundings. This view was substantiated by the result of the present experiment showing that slight injury or mere prick with a needle of the pituitary gland which might induce liberation of the pituitary principle into the blood caused complete ovulation in the operated animal and that susceptibility for injection of the pregnancy urine which was too effective for induction of ovulation was perceptibly higher in hypophysectomized animal than in intact ones, possible cause of such a fact being considered to be temporary liberation into the blood of slight amounts of the pituitary hormone in the hypophysectomized animals at the time of operation. It was concluded that sufficient amounts of the pituitary hormone is preserved in the gland of animals in captivity but its liberation is hindered under the circumstance. It was further deduced that the intact pituitary gland of the animal's own does not concern in any significant way with the artificial induction of ovulation by means of injection of the anterior pituitary hormone. M. Enami.

131. Precocious Development of the Silk Gland following Ablation of the Corpora allata in the Silkworm. (Japanese with English resume.) Soichi FUKUDA [Zool. Mag. (Tokyo), 54 (1) (1942), 11–13, 2 Text figs.] Morphological as well as functional development of the silk gland in the silkworm was remarkably accelerated as the result of extirpation of the corpora allata. The operation was performed on the 3rd or the 4th day of the 3rd or the 4th instar, and the operated larvae began to form the cocoons in 3 or 4 days following the operation showing remarkable prematurity in contrast to intact larvae which were at those times on the 2nd day of the 4th instar or on the 1st or the 2nd day of the 5th instar. The silk glands of the operated larvae spinning their cocoons were very well developed, taking the appearance of miniature mature glands, while those of the control animals were still in a quite undeveloped state. M. Enami.

132. Rare Fishes from Kii and Tosa, Japan. (Japanese.) Toshiji KAMOHARA [Zool. Mag. (Tokyo), 54 (1), (1942), 25–28, 1 Text fig.] — Fifteen species including several rarely known ones collected in the Provinces of Kii and Tosa are reported. M. Enami.

133. Induction of Ovulation in *Onychodactylus japonicus* (Houttuyn) by Intercepting the Solar Effect. (Japanese.) Dyohati NAKAMURA [Zool. Mag. (Tokyo), 54 (2) (1942), 51–59, 3 Text figs., 7 Tabs.] In this paper is reported a new method of artificial induction of ovulation in *Onychodactylus* which has long been known to be incapable of ovulation under experimental laboratory conditions. The method consists simply of shutting off the effect of sunlight, the animals being retained in water of low temperatures (10–14 C). Under such circumstance ovulation took place in ca. 2 weeks, ca. 3 days having been required for completion of ovulation. The author is of opinion that the usual inhibition of ovulation in animals in captivity may be due to inhibition of activation of the anterior pituitary hormone by the effect of sunlight and release of the pituitary activity from the solar effect may result in ovulation.

M. Enami.

134. Sur une Nouvelle Espèce de Trématode du Genre *Coitocoecum*. (Note préliminaire.) Toji OGATA. [Zool. Mag, (Tokyo), 54 (2), (1942), 85–88, 2 Figs.]—Description d'une nouvelle espèce de trématode, *Coitocoecum palaoensis*, n. sp., obtenue à l'ile de Palao de l'intestin grêle d'un poisson, *Toxotes jaculator*. M. Enami.

135. On the Rearing and Metamorphosis of *Balanus amphitrite hawaiiensis* Broch. (Japanese with English résumé.) Motosaku HUDINAGA and Hirosi KASAHARA. [Zool. Mag. (Tokyo), 54 (3), (1942), 108–118, 11 Text-figs.]—The authors succeeded in rearing the larvae of the barnacles, *Balanus amphitrite hawaiiensis*, *B. a. albicostatus* and *Tetraclita squamosa*. The last-named species succumbed before settling, but the former 2 attained the adult forms. Method of rearing was much the same as in the case of rearing the zoea of *Penaeus japonicus*, the barnacle larvae having been fed with artificially cultured diatom, *Skeletonema costata*. Detailed description of the developmental process in *B. a. h.* is given. M. Enami.

136 Termites from Palao Islands. Masamitsu OSHIMA. [Palao Trop. Biol. Stat. Stud., 2 (3), (1942), 381–389, 5 Text-figs.]—Four species of termites commonly found in the Palao Islands are studied from the morphological view-point. They are *Calotermes (Neotermes) kanehirae*, *Eutermes (Grallatotermes) brevirostris*, *E. (Eutermes) paluoensis*, n. sp., which attack chiefly the coconut palm, and *Rhinotermes (Schedorhinotermes) longirostris*, the most common species infesting all sorts of wooden structures. M. Enami.

137. Bopyrids from the South Sea Islands with Description of a Hyperparasitic Cryptoniscid. Sueo M. SHIINO. [Palao Trop. Biol. Stat. Stud., 2 (3), (1942), 437–458, 7 Text-figs.]—Following species of Bopyrids collected at various localities in the South Sea as well as from Australia are reported: *Bopyrina miyakei*, n. sp., *Aporobopyrus ryûkyûensis*, *Aporobopyrosa pacifica*, n. gen. n. sp., *Merocepon xanthi*, *Dactylocepon palaoensis*, n sp., *Grapsicepon micronesianum*, n. sp., and *Scyracepon oceanicum*, n. sp. One of the specimens of the last-named was found to contain in its brood-pouch a new Epicaridean hyperparasite, *Cabirops tuberculatus*, n. sp., description of which is added. M. Enami.

138. On a Collection of the Fishes at the Palao Islands. Hyozi AOYAGI. [Palao Trop. Biol. Stat. Stud., 2 (3), (1942), 459–467, 9 Text-figs.]—Twenty-four species collected from the Palao waters are briefly dealt with. M. Enami.

139. Taxonomic Studies on the Puffers (Tetraodontidae, Teleostei) from Japan and Adjacent Regions. I. Vertebral Varaiation. Tokiharu ABE. [Palao Trop. Biol. Stat. Stud., 2 (3), (1942), 477–496, 2 Pls., 2 Text-figs., 12 Tabs.]—Examination of a large number of materials belonging to the family Tetraodontidae obtained from waters of Japan and its adjacent regions rendered results indicating that the vertebral column may be of use as an indicator of natural affinity among the fish in question. The genera can be segregated from each other by the number or the form of vertebrae, but closely allied species are hardly distinguishable from one another by the features of the vertebrae. M. Enami.

140. On the Feeding Habit of a Holothurian, *Stichopus japonicus* Selenka. Toshihiko YAMANOUTI. [Zool. Mag. (Tokyo), 54 (9), (1942), 344–346, 1 Text-fig., 2 Tabs.]—Feeding activity of *Stichopus japonicus* takes place discontinuously at irregular intervals throughout the day, no obvious diurnal rhythmicity being detected. This fact differs from the remarkable monophasic diurnal activity observed in other species of the genus *Stichopus*, such as *S. variegatus*, *S. chloronotus*, etc. A summary of types of the feeding behavior hitherto examined in 10 species of Holothurians is added. M. Enami.

141. Discrimination of Number Given in the Form of Visual Stimuli in the Tortoise *Clemmys japonica*. (Japanese with English résumé.) Noboru OHTSUKA. [Zool. Mag. (Tokyo), 54 (5), (1942), 167–171, 1 Text-fig., 5 Tabs.]—Training experiments were carried out to test the possibility of discrimination of number in *Clemmys japonica*. Results show that the animal is able to distinguish 2 figures from 1 or 3 irrespective of the form, size and spacing of figures employed. M. Enami.

142. On the Chromosomes of Four Species of Crabs (Brachyura, Decapoda). (Japanese with Englich résumé.) Hidejiro NIIYAMA. [Zool. Mag. (Tokyo), 54 (8), (1942), 302-306, 4 Text-figs.] — Numbers and morphological features of the chromosomes observed in the male germ cells of 4 species of crabs are reported. Following table summarizes the principal results of the study. M. Enami.

Species	Chromosome Number			Formula
	2n		n	
Matuta lunaris	94	spg	47 (I, II)	4 V+90 r
Ranina ranina	106	spg	53 (I, II)	24 V+82 r
Scylla serrata	106	spg	53 (I, II)	all rods
Telmessus cheiragonus	124	spg	62 (I, II)	8 V+116 r

In this table spg indicates the spermatogonium, I the primary spermatocyte, II the secondary spermatocyte, V the V-shaped chromosome and r the rod-shaped chromosome. Presence of any specialized chromosome was not proved in the spermatogenesis of the species examined.
M. Enami.

143. Regeneration of the Tail and Tail-Fin in Teleost. (Japanese with German résumé.) Hidesi MORI. [Zool. Mag. (Tokyo), 54 (3), (1942), 119-124, 1 pl., 8 Text-figs.] — Mode of regeneration of cut tail and tailfin in the killifish, *Oryzias latipes*, was examined with the conclusion that neither the stump of fin-ray nor the basal plate is decidedly necessary for regeneration of the injured parts, regenerating process is markedly affected by temperature, whose optimum range is considered to be 25-29°C, the younger the operated animal is the stronger is the regenerating power, etc. M. Enami.

144. Ascidians Found on the Mangrove Trees in Iwayama Bay, Palao. Takasi TOKIOKA. [Palao Trop. Biol. Stat. Stud., 2 (3), (1942), 497-506, 1 Pl., 2 Text-figs., 1 Tab.] — Descriptions are given of 2 species of compound ascidians, *Polycitor (Eudistoma) olivaceus* and *Leptoclinum virens*, found attaching to the mangrove trees at the Korror Island, Palao Islands. A short note with reference to an experiment on the oxygen-productivity of zoochlorellae included in *Leptoclinum virens* is added. M. Enami.

145. Systematic Studies of the Plankton Organisms occurring in Iwayama Bay, Palao. I. Introductory Notes, with some References to the Surface Water Temperature and the Settling Volume of Planktons in the Bay. Takasi TOKIOKA. [Palao Trop. Biol. Stat. Stud., 2 (3), (1942), 507-519, 5 Tabs.] — Distribution of the surface water temperature was studied with the intention to outline the range of the littoral characters of the water in Iwayama Bay, a lagoon within a lagoon, being enclosed by the Korror Island and the Orupusyakaru Island, Palao Islands. Settling volume of the plankton collected at various sites in the Bay was dealt with in comparison with the result of temperature measurements. M. Enami.

146. Systematic Studies of the Plankton Organisms occurring in Iwayama Bay, Palao. II. List of Diatoms occurring in the Bay. Yosiyuki MATUE. [Palao Trop. Biol. Stat. Stud., 2 (3), (1942), 521-525.] — Seventy-six species of diatoms collected in the Iwayama Bay are listed. M. Enami.

147. Systematic Studies of the Plankton Organisms occurring in Iwayama Bay, Palao. III. Chaetognaths from the Bay and Adjacent Waters. Takasi TOKIOKA. [Palao Trop. Biol. Stat. Stud., 2 (3), (1942), 527-548, 3 Pls., 11 Text-figs.] — Chaetognaths collected in the Palao lagoon, the waters surrounding the Palao Islands and those from the Arafura Sea are reported. *Sagitta tropica*, n. sp., and *S. lacunae*, n. sp., are described as new to science.
M. Enami.

148. Systematic Studies of the Plankton Organisms occurring in Iwayama Bay, Palao. IV. Copepoda from the Bay and Adjacent Waters. Takamochi MORI. [Palao Trop. Biol. Stat. Stud., 2 (3), (1942), 549-580, 7 Pls.] — Fifty-four species of adult forms and 7 species of immature stages of Copepoda are reported from the waters surrounding the Korror Island, Palao Islands. Following 3 new species are included: *Acartia tokiokai*, n. sp., *Idyellina elongata*, n. sp., and *Spinocalanus pacificus*, n. sp. M. Enami.

149. Systematic Studies of the Plankton Organisms occurring in Iwayama Bay, Palao. V. Two Planktonic Suctorians from Palao. Kanefumi NOZAWA. [Palao Trop. Biol. Stat. Stud., 2 (3), (1942), 581–584, 1 Pl., 2 Text-figs.]—*Ephelota pusilla* found attached on the shell of the veliger larva of a gastropod and *E. gemmipara* found on the abdomen and appendages of *Calanus vulgaris* are reported. M. Enami.

150. Systematic Studies of the Plankton Organisms occurring in Iwayama Bay, Palao. VI. On Brachyuran Larvae from the Palao Islands (South Sea Islands). Hiroaki AIKAWA. [Palao Trop. Biol. Stat. Stud., 2 (3), (1942), 585–611, 18 Text-figs.]—Types of zoeas collected from the Palao waters are classified and the zoeal community in the Iwayama Bay is discussed. M. Enami.

151. Systematic Studies of the Plankton Organisms occurring in Iwayama Bay, Palao. VII. A preliminary Report on the Appendicularian Fauna of the Bay and the Adjacent Waters. Takasi TOKIOKA. [Palao Trop. Biol. Stat. Stud., 2 (3), (1942), 613–616.]—Lists of Appendicularians collected in the Iwayama Bay, in the neighboring waters of the Palao Islands and from the Arafura Sea are given. M. Enami.

152. On the Alliedness of the Japanese and the California Sardine, a Morphological and Statistical Study. Ikusaku AMEMIYA and Osamu TAMURA. [Journ. Coll. Agric., Tokyo. Imp. Univ., 15, No. 2 (1942), 133–180, 15 Text-figs., 4 Pls. and 12 Tabs.] The Japanese and the California sardine, *Sardina melanosticta* and *S. caerulea*, were compared with respect to each body part morphologically and to the means of measurements of characters statistically. Between the two fishes no morphological difference can be found, such as in the structure of the processes of gill-raker, the ventral scutes and the opercle. Differences existing between the two fishes are those characters which can only be found by statistical comparison, namely, the head-length, number of ventral scutes and number of vertebrae. The head-length of the Japanese sardine is longer by 1.5–2.3% in the body-length than that of the California sardine. The number of ventral scutes of the Japanese sardine (34.3–34.4) is 1.3–1.4 less than in the California sardine (35.7). The number of vertebrae in the Japanese sardine (50.761±0.0048) is just one less than that in the California sardine (51.67±0.0046), while the histograms of vertebral number in "All Japan" and "All America" sardine show the common area of 40.1%. The authors are of opinion that the degree of difference between the two sardines should be regarded as that occurring in one species, namely, between varieties or subspecies. Authors.

153. A New Hereditary Type of Rumplessness in the Fowl. (Japanese with English résumé.) Bumpei HAYASI. [Jap. Jour. Genet., 18 (5), (1942), 251–260, 9 Text-figs., 4 Tabs.]—Tailless domestic fowls appeared sporadically as an occasional occurrence in a flock of normal-tailed white Leghorns under rearing at Sapporo. From a morphological study they were known to be completely lacking one or two synsacral vertebrae, the free caudal vertebrae and the pygostyle. Such forms are to be designated as cases of the rumplessness. Some genetical experiments were undertaken with a view to determine whether or not the rumpless character in these birds is heritable in the same sense as that reported by Dunn and Landauer. Results were very illuminating, showing that the character in question might be inherited by a simple, Mendelian recessive gene, which may be symbolically represented as *r*. M. Enami.

154. Notes on the Chromosomes of *Brachytrupes portentosus* (Gryllinae, Gryllidae). (Japanese with English résumé.) Eizi MOMMA. [Jap. Jour. Genet., 18 (6), (1942), 309–312, 8 Text-figs.]—Individual variation is the remarkable feature known in the chromosome number of the large brown cricket of Taiwan. In addition to six different types hitherto reported by Tateishi and Ohmachi, the present writer found two other chromosome complexes, viz., 5 V's+2 J's+7 rods+X and 5 V's+2 J's+7 rods+2 m-chroms.+X. M. Enami.

155. Genetical Studies on the Colour of the Egg and Eye in the Silkworm. (Japanese.) Kanichiro SUZUKI. [Jap. Jour. Genet., 18 (5), (1942), 279–284, 4 Tabs.]—A review of the recent acquisitions concerning the genetical problems relating to coloration of the egg and eye in the silkworm. M. Enami.

156. On the Species Hybrid of *Rana japonica* ♀ × *Rana temporaria temporaria* ♂. (Japanese.) Tosiziro KAWAMURA. [Jap. Jour. Genet., 18 (3), (1942), 135-138, 3 Tabs.] — A cross between *Rana japonica* ♀ and *R. temporaria temporaria* ♂ was successful in producing the hybrid males that attained the maturity. Observations upon the hybrid tadpoles as well as upon the animals after metamorphosis showed that the hybrid forms are provided with the morphological characters which are approximately intermediate between those of the parents except for several features in which the hybrids approach more closely to *R. temporaria temporaria* than to *R. japonica.* Inspection of the gonad of the mature hybrid male disclosed several peculiarities: the spermatozoa are very scarce and enormous in size, and there are indications suggesting that the spermatogenesis in the hybrid may be of wholly different procedure as compared with the normal events in the frogs. A back-cross attempted between such hybrid males and the female of *R. japonica* was proved to be failure. The same was the case in a cross of *R. temporaria temporaria* ♀ × *R. japonica* ♂. M. Enami.

157. A Case of the Mosaicism in the Silkworm Egg, Probably due to a Recessive Mutation. (Japanese with English résumé.) Yataro TAZIMA. [Jap. Jour. Genet., 18 (6), (1942 , 305-308, 3 Text-figs., 1 Tab.] — Application of a high temperature of 40° ± 1°C to the silkworm eggs obtained from a crossing of ($P^s\,Y/P^s\,Y$, $Re\ Pe/Re\ Pe$)♀ × ($P\ y/P\ y$, $re\ pe/re\ pe$)♂ produced a number of the mosaic eggs, of which four gave rise to the caterpillars. One of the caterpillars, which was heterozygous striped, developed to a female moth provided with a mosaic eye consisting of black and pink facets. From an experiment in which this female moth was mated to a ($p\ y/p\ y$, pe/pe) male, it was known that *Pe pe* ratio was quite abnormal, which is to be attributable to certain abnormal behavior of the *Pe* gene. Such may be interpreted as a result of the recessive mutation of *Pe* to *pe* in the two cell stage. M. Enami.

158. Genetical Studies of the Lady-Bird Beetle, *Harmonia axyridis* Pallas. VI. (Japanese with English résumé.) Yasusi HOSINO. [Jap. Jour. Genet., 18 (6), (1942), 285 296. 36 Text-figs., 21 Tabs.] – In the continuation of the foregoing experiments concerning the inheritance of the elytral patterns in *Harmonia axyridis* this report is dealing with the type of *succinea*, the most recessive character of the elytral patterns that have been known to be inherited by the allelomorphic genes located on the autosomes. Six conspicuous subtypes of *succinea* (*succinea*-1, *succinea*–2, etc.) might be elicited experimentally chiefly through the effect of the environmental temperature, which were served as the materials for crossings of various combinations. As the result it was established that each of such subtypes of *succinea* may be due to a factor (p^1 = factor for *succinea*–1, p^2 = for *succinea*-2, etc.) belonging to the same allelomorphic series as *conspicua* (P^C), *gutta* (P^G), *distincta* (P^D), etc., and they may behave as recessives to all the latter types. M. Enami.

159. The Chromosomes of *Scolopendra damnosa* L. Koch (Chilopoda). Sajiro MAKINO and Hidejiro NIIYAMA. [Jap. Jour. Genet., 18 (1), (1942), 34 40, 15 Text-figs.] - A study on the chromosomes of *Scolopendra damnosa* was carried out upon the male sexual cells with the result that the chromosome number in the spermatogonium is 28 (2 n) and that in the spermatocyte is 14 (n). The information hitherto reported that the centipedes have the sex-chromosome of X-O type is denied from the present study. M. Enami.

160. On the Hybrid between the Domestic Fowl, *Gallus gallus* var. *domesticus*, and the Common Pheasant, *Phasianus colchicus*. (Japanese with English résumé.) Marq. Yoshimaro YAMASHINA. [Jap. Jour. Genet., 18 (5), (1942), 231-253, 5 Pls., 28 Text-figs., 2 Tabs.] — Hybridization experiments were realized between the domestic fowl and the common pheasant, the cross between these forms being made without any difficulty in captivity. From various combinations of the parent birds 164 hybrid eggs were obtained, of which 46 eggs were proved to be fertilized, and 9 unhatched embryos, 12 chicks and 9 adults being finally produced. Analysis of these hybrid offsprings showed that, notwithstanding previous informations stating that the males were produced in excess from the similar cross, the sex-ratio in the present case was approximately 1 : 1. It was remarkable that the female hybrids largely sucumbed during the incubating period and also in the early stage of the chick, the result suggesting that previous authors might have worked upon the adults only. The most successful combination was the Red-

hackled Shamo ♂ × the Korean Ring-necked Pheasant ♀ which rendered a high fertility of 37%, other combinations, e. g., the Black Shamo ♂ × the Korean Ring-necked Pheasant ♀ and the Red-hackled Shamo Bantam ♂ × the Korean Ring-necked Pheasant ♀, each showed a fertility of nearly 13%. Feather patterns and other external characters of the resultant offsprings and some ecological features of them are examined. Sex-hormone injection was carried out in two F_1 males of 24 months old with no remarkable effect upon the activity of the germ cells.
M. Enami.

161. On the Chromosomes of *Hydra*. (Japanese.) Hidejiro NIIYAMA. [Jap. Jour. Genet., 19 (1), (1943), 46]—Chromosomes of three species of *Hydra* are reported. *Hydra vulgaris attenuata* has 32 chromosomes in 2n, *H. circumcincta* 30 (2n) and *Pelmatohydra oligactis* 30 (2n).
M. Enami.

162. On the Chromosomes of Some Species of the Zygopterous Dragonflies (Odonata, Zygoptera). (Japanese with English résumé.) Hisao KICHIJO. [Jap. Jour. Genet., 18 (5), (1942), 273-276, 43 Text-figs.]—Chromosome numbers were examined in the male germ cells of seven species of the dragonflies belonging to Lestidae and Coenagriidae (Zygoptera-Odonata). Results were as follows.

Species	Chr Number	
	2n	n
Lestes sponsa	25	13
Sympycna fusca	(25)	13
Agrion hieroglyphicum	(27)	14
A. sp.	(27)	14
Ischnura senegalensis	(27)	14
Agriocnemis selenion	(27)	14
Copera annulata	(25)	13

M. Enami

163. Biochemical Studies on Factors augumenting Lactation. I. Extraction of Lactating Hormone from Pig Liver. Iwao IWAMURA. [Jap. Jour. Zootech. Sci., 14 (2), (1941), 57-59, 2 Tabs.]—Prolactin was extracted from the pig liver.
M. Enami.

164. Studies on the Thermophilous Animals of Japan (XXXII). The Fauna of Hakone Hot Springs. (Japanese.) Yuichi ITO and Mitsuo UYEMURA. [Jap. Jour. Limnol., 12 (2), (1942), 50-55, 3 Text-figs., 1 Tab.]—Fauna characteristic of five hot springs surrounding Hakone was dealt with.
M. Enami.

165. On the Habits and Early Development of *Pseudosciaena crocea* (Richardson). (Japanese.) Tetuo YAMADA. [Suisan Gakkwai Ho, 8 (3, 4), (1941), 184-189, 2 Text-figs.]—*Pseudosciaena crocea*, which is economically of considerable importance along the coast of the Yellow Sea, is dealt with in its curious habit of sound production and the developmental course within the egg.
M. Enami.

166. The Fauna of the Acid Streams in Japan (2). (Japanese.) Yosikazu KASAI. [Jap. Jour. Limnol., 12 (2), (1942), 56-62]—In the continuation ot the report (1) this paper comprises some biological remarks as regards the important groups of animals found in thirteen acid streams in Japan. Animals that were found to inhabit the water of $pH < 5.0$ are Coleoptera (25 spp.), Trichoptera (15 spp.), Diptera (11 spp.), Heteroptera (8 spp.), Plecoptera (5 spp.), Neuroptera (5 spp.), Ephemeroptera (4 spp.) and other groups (7 spp.). *Rhyacophila towadensis*, *Protonemoura* sp., *Notonecta triguttata*, *Sigara substriata*, *Protohermes grandis*, a species of Empidae, *Eukiefferiella* sp. and *Polypedilum* sp. were obtanied from the water of $pH < 2.0$. M. Enami.

167. On the Fishes of the Genus *Collichthys* caught in Korean Waters. (Japanese.) H. YABE [Suisan Gakkwai Ho, 8 (3, 4), (1941), 173-183, 13 Text figs., 3 Tabs.]— Notes on the morphology and biology of *Collichthys fragilis* and *C. niveatus* which were caught near Chosen (Korea), are given. Attention is called to their ecomical value. M. Enami

168. Gametogenesis and the Breeding Season of the Japanese Common Scallop, *Pecten* (*Patino-*) *yessoensis* Jay. (Japanese with English resume.) Gotarô YAMAMOTO [Bull. Jap. Soc. Sci. Fish. 12 (1), (1943) 21-26, 1 Text fig.] An inquiry into the gametogenesis in the Japanese common scallop in the Mutsu Bay, Aomori Pref., was done with the following results. Fully grown ova and spermatozoa are found during the period from Feb. to June, active spawning in its full scope from Apr. till May. From Mar. on the artificial fertilization is possible. Maturation of the male gonad was observed in the one year old individuals showing that the male is sexually active in the second year of the development. M. Enami

169. Effects of Low Specific Gravity of the Medium and Exposure to Air on the Bath Sponge *Euspongia officinalis*. (Japanese with English resumé.) Tadasi TAMURA and Yosito KAWAGOE [Bull. Jap. Soc. Sci. Fish., 12 (12), (1943), 27-29, 2 Tabs.] Resistance of *Euspongia officinalis* against lowering of the specific gravity of the environmental sea water and that against exposure to the air were examined in connexion with the problem of conditioning the cultivating milieu for the sponge. It was observed that the range of lower specific gravity as low as 1 did not induce the death of the animal for five hours of immersion. However 15-20 hours' sojourn of the sponge in the medium of 1.00507-1.00000 of specific gravity was fatal. The sponge was able to withstand exposure to air under 29.1 C for 15 hours, but died in 24 hours. M. Enami

170. Phyllosomae of the Genus *Panulirus*. (Japanese.) Y. OSIMA [Suisan Gakkwai Ho, 9 (1) (1942) 36-44, 8 Text figs. 4 Tabs.] Morphological study of phyllosomae chiefly collected from the Japanese waters. In the specimens examined two types were recognized, which were respectively dealt with as Form E and Form F after Gurney's designation of Forms A, B and D. A key for the identification of phyllosomae of the Genus *Panulirus* hitherto known is added. M. Enami.

171. Observations on the Spawning and Age of *Hypomesus olidus*. (Japanese.) Ikusaku AMEMIYA and Yoshio HIYAMÁ [Suisan Gakkwai Ho, 8 (1), (1940), 40-62, 4 Text figs., 11 Tabs.] From study of the scales of *Hypomesus olidus* obtained from the Lake Kasumiga Ura, the writers arrived at a conclusion that age determination might be possible by enumeration of the bands which are represented by difference in width between any successive circuli, assuming that the wider bands being formed in the summer and the narrower ones in the winter. Upon the basis of various lines of evidences gained from the studies of the scale marks these authors are of opinion that the fish is to be considered to spawn after one year, and in the second year ca. 1/4 of them survives to spawn. Thereafter ca. 1/5 of the fish that have completed the second spawning remains, of which very small number of individuals conduct the third spawning. No specimen was obtained which shows any decided indication of performance of the fourth spawning. The fish grows up to 8 cm in one year and to 9-10 cm in two years in the Lake. M. Enami

172. Growth of Scales of Salmonid-Type under Rearing Experiment. (Japanese.) Yoshio HIYAMA [Suisan Gakkwai Ho, 8 (2), (1940), 105-115, 5 Text figs., 2 Tabs.] In spite of the common application of the method of age determination from the study of morphological features marked on the fish scales, no extended attempt has been made as regards the experimental reasoning of the conception. This report affords several evidences proving the adequateness of the method in the Salmonid type of scales. Work was done with *Oryzias latipes* that had come from the same strain and had been spawned on the same day. A lot of the individuals was reared for 1/2 year in an outdoor pond and was fed well, while another lot was confined for one year in a laboratory aquarium under scanty nourishment. Examination of the scales of these respective lots showed that the environmental condition in the first lot was appreciably impressed in various distinguished features on the scale, difference between the scale features of either lot being significant in the mean values, not in individual comparison. M. Enami.

173. Migratory Habit of *Meretrix meretrix*. (Japanese.) Keitaro UCHIDA. [Suisan Gakkwai Ho, 8 (3, 4), (1941), 3 Text-figs., 5 Tabs.] — Immature clam *Meretrix meretrix* performs an interesting mode of rapid migration protruding a long transparent viscous cord from the posterior part of the shell, the clam itself being trawled by the cord in the direction of the ebb-tide current by which it is drawn adrift. Owing to such a passive mode of locomotion the clam can make considerable distance with velocity as nearly as that of the occasional current. Active migration was observed from the early summer to the autumn, activity reaching its height in Aug. Direct motive for the activity is supposed to be associated with the need during the developmental course for the habitat of deeper water. M. Enami.

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